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EFFECT OF AIRPLANE DISTRIBUTED DDT THERMAL AEROSOLS ON FISH AND FISH FOOD ORGANISMS[1]

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During the summers of 1943 and 1944 the Tennessee Valley Authority carried out extensive laboratory and field investigations to determine the effectiveness of various DDT formulations as anopheline larvicides. These investigations resulted in the development of a promising method for distributing DDT thermal aerosols by airplane (Metcalf *et al.*, 1945). Extensive field demonstration tests were carried out during 1945 to determine the feasibility of adopting airplane distributed DDT thermal aerosol in place of Paris green as a larvicide for routine use to control the malaria mosquito, *Anopheles quadrimaculatus*, on the Authority's impoundments. In connection with these field demonstrations, studies were made to determine the effect of DDT applied in this manner upon fish and fish food organisms since it had been observed previously that DDT solutions and emulsions were toxic to many forms of aquatic life when applied in excessive dosages. Such studies were in line with the Authority's policy of selecting malaria control procedures which are the least injurious to wildlife.

The present paper summarizes observations on the effect of DDT thermal aerosols distributed by airplane at the rate of approximately 0.1 lb. DDT per acre upon fish and fish food organisms both from the standpoint of individual treatments and cumulative treatment over an entire season.

MATERIALS AND METHODS

The formulation used in these studies was a 20 per cent solution by weight of technical grade DDT [2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane] in a methylated naphthalene.[2] The material

[1] Dr. A. H. Wiebe gave much helpful advice during the planning of the studies and provided two biological aides to assist in collecting the field data. Dr. R. W. Eschmeyer and Mr. D. E. Manges participated in the determinations of fish populations, and Dr. Eschmeyer made the calculations of K values in Table 4. Mr. C. D. Fairer and members of his staff also assisted with the fish population studies. The airplane application of the DDT thermal aerosols was ably carried out by Mr. Charles Bradford.

[2] Velsicol NR-70, Velsicol Corporation Chicago, Illinois.

was applied in the form of a thermal aerosol or "mist" by means of the Authority's Stearman Model 4-DX dusting planes equipped with venturi exhaust generators (Metcalf *et al.*, 1945; Krusé and Metcalf, 1946). The aerosol had a mass median diameter of 35 to 40 microns and about 50 per cent of the total number of particles were less than 25 microns in diameter. The rate of application was approximately 0.1 lb. DDT per acre based on a 100-foot swath; however, the actual rate of recovery ranged from 0.012 lb. DDT per acre at the center of the swath to about 0.001 lb. per acre 100 feet from the center of the swath. This application rate gave effective kills (90 per cent) of anopheline larvae over swaths ranging from over 200 feet wide in areas with light vegetative cover to 60 feet in areas with heavy vegetative cover.

Determinations of populations of aquatic organisms were by the screen dipper and strainer pan technique (Hess, 1941; Hess and Tarzwell, 1942). The organisms studied were therefore those inhabiting a stratum of water extending approximately two inches beneath the surface. However, general observations were also made upon bottom dwelling and surface inhabiting (supraneuston) forms. The studies were limited entirely to macroscopic forms although some counts and identifications were made under a binocular dissecting 'scope. Plots were dipped the day before treatment and the day after treatment. In most instances, sufficient samples (usually 15) were collected in each series to keep the standard error within 10 per cent of the mean.

Four general types of data were obtained on the effect of the DDT aerosols upon aquatic organisms which might serve as food for fishes:

1. Before and after dipping at the center of single swaths to determine the maximum effect of individual treatments.
2. Before and after dipping in transect across areas receiving routine area treatment (overlapping swaths flown at 100-foot intervals) to determine the average effect of individual area treatments.
3. Seasonal comparisons of populations of aquatic organisms in areas treated at weekly intervals and comparable untreated check areas to determine residual and cumulative effects of routine treatment.
4. Measurement of populations at the end of the season in areas receiving weekly treatments throughout the season to determine the kinds of organisms surviving a full season of treatment under varying environmental conditions.

In order to determine the effects of DDT thermal aerosols upon fish populations, two backwater areas of Wheeler Reservoir were dammed off from the main lake during the early spring to prevent fish from entering or leaving the areas. These entire areas were then subjected to routine weekly treatments of DDT throughout the season, thus insuring that the resident fish populations would be exposed to a full season's dosage of DDT. At the end of the season the areas were treated with rotenone in order to measure the surviving fish population, the procedure being similar to that used by Tarzwell (1940).

RESULTS

EFFECTS UPON FISH FOOD ORGANISMS

The results of dipping studies to determine the effects of DDT thermal aerosols upon fish food organisms are summarized in Table 1. In the first

column is shown the maximum reduction in populations of aquatic organisms as determined by before and after dipping at the center of the treatment swath. It will be observed that three groups showed essentially a 100 per cent reduction, namely, anopheline and culicine mosquitoes and surface Hemiptera. The anophelines were practically 100 per cent *A. quadrimaculatus*, and most of the culicines were *Culex erraticus*. The Hemiptera were mostly common species of *Gerris*, *Trepobates*, and *Hydrometra*. Two other groups were significantly reduced, aquatic Coleoptera and amphipod crustacea. The Coleoptera (both larvae and adults) were mainly of the families Dytiscidae and Hydrophilidae and included the genera *Coptotomus*, *Hydrocanthus*, and *Tropisternus*.

None of the other groups present appeared to be significantly affected. The subsurface Hemiptera present were mainly *Trichocorixa burmeisteri* with occasional specimens of *Belostoma*, *Ranatra*, and *Notonecta*. The Odonata included several species of both Zygoptera and Anisoptera, the most abundant species being *Erythemis simplicicollis*, the young nymphs of which commonly inhabit accumulations of flotage and subsurface debris. The Diptera were mainly Chironomidae and Ceratopogonidae (near *Bezzia*); tabanid larvae (*Chrysops*) were common also. Most Ephemeroptera were of the genus *Caenis*. The Entomostraca included Cladocera, Copepoda, and Ostracoda.

In column 2 of Table 1 is shown the average effect of individual applications

TABLE 1.—EFFECT UPON AQUATIC ORGANISMS OF DDT THERMAL AEROSOLS APPLIED BY AIRPLANE AT THE RATE OF APPROXIMATELY 0.1 LB. DDT PER ACRE (WHEELER AND KENTUCKY RESERVOIRS, JULY–SEPT., 1945).

Organisms	Effects upon Populations of Aquatic Organisms					
	Immediate effect				Residual effect*	
	Maximum effect center of swath (100 sq. ft. samples)		Routine area treatment (150 sq. ft. samples)		Treated vs. check area (180 sq. ft. samples)	
	No. per sq. ft. before treatment	% Change	No. per sq. ft. before treatment	% Change	No. per sq. ft. in check area	% Difference
Anophelini	2.9	−98	3.4	−98	0.8	−71
Culicini	3.0	−97	3.9	−59	1.4	−31
Surface Hemiptera	0.7	−100	0.4	−95	0.3	−62
Subsurface Hemiptera	0.4	−13	0.5	+19	0.5	+ 2
Coleoptera	0.7	−48	1.2	− 4	1.2	+20
Diptera (except Culicidae)	2.6	− 9	1.8	+16	0.9	+ 7
Odonata	9.1	+ 9	6.6	+18	2.5	0
Ephemeroptera	0.5	− 11	2.5	+ 5	0.8	+17
Hydrachnidae	3.5	− 16	—	—	—	—
Amphipoda	5.7	− 48	—	—	—	—
Entomostraca	14.2	+ 1	Abundant	0	Abundant	0
Gastropoda	1.3	+ 4	0.6	0	1.2	+43
Planaria	1.2	+ 17	—	—	—	—
Araneae	0.9	− 8	0.6	+14	0.3	+ 9

* Treated and check areas sampled 1 week after treatment.

as determined by before and after dipping along transects across areas receiving routine treatment with flight swaths at 100-foot intervals. Anopheline mosquitoes and surface Hemiptera were almost completely eliminated on an area basis. The area reduction of culicine mosquitoes, however, was much less than at the center of the swath, the dosage of DDT at the sides of the swaths apparently being insufficient to give effective kills. None of the other groups showed significant reduction on an area basis.

In column 3 of Table 1 are shown the average differences between populations of organisms in an area receiving routine weekly treatments and in an adjacent untreated area. The two areas both contained American lotus (*Nelumbo pentapetala*) and were quite comparable with reference to aquatic fauna. The data were collected at weekly intervals over a 5-week period during July and the first part of August, and the dipping was done on the day before treatment in both the treated and untreated areas. The treated area received routine weekly applications at the rate of 0.1 lb. DDT per acre beginning the last week in May. The results therefore show not only the cumulative effects of the routine weekly treatments but also (by comparison with data from individual treatments) the average extent of recovery at the end of each week following treatment. Only three groups, anopheline and culicine mosquitoes and surface Hemiptera, showed significant reduction by comparison with the check area. The anophelines and the Hemiptera showed some recovery during the week after treatment, but were still only about one-third as abundant as in the check area. Culicine mosquitoes showed more complete recovery, becoming two-thirds as abundant as in the check area by the end of the week.

In addition to the studies summarized in Table 1, other observations were made on the effect of the treatments upon aquatic and terrestrial forms. At the end of the season two areas which had received weekly treatments from May 29 to September 11 were sampled to determine what aquatic forms were still abundant. Organisms which were still present in great abundance on September 24 and 25 included the following: Chironomidae (bottom dwelling species of *Chironomus*); Corixidae (mostly *Trichocorixa burmeisteri*); Anisoptera and Zygoptera; Ephemeroptera (mostly *Caenis* sp.); *Podura aquatica;* Gastropoda (mostly *Physa* sp.); Annelida (mostly tube dwellers in the surface trash, probably of the genus *Dero*); Cladocera, Copepoda (many with egg sacs), and Ostracoda; Hydrachnidae; Arachnidae; and the colonial rotifer, *Conochilus.* Forms which were not abundant but probably present in normal numbers included: Chironomidae (surface debris forms); Ceratopogonidae (near *Bezzia*); Notonectidae (including *Plea striola*); Coleoptera (including Dytiscidae, Hydrophilidae, Haliplidae, and Gyrinidae); Trichoptera; and the decapod crustacean, *Palaemonetes.* Conspicuous by their absence were the surface Hemiptera. The common species of *Gerris, Trepobates,* and *Hydrometra* which inhabit the area apparently were almost completely eliminated.

By means of counts made within floating wooden frames, some observations were also made on the effects of

the DDT aerosol treatments upon aerial forms of insects. At the normal rate of application one form appeared to be particularly susceptible, a small fly of the family Dolichopodidae, genus *Pelastoneurus*. The habit of these flies of running over the water surface probably made them more susceptible to the DDT treatments. The high susceptibility of surface Hemiptera was also confirmed by these studies and there was some evidence of a partial kill of Corixidae in the center of the swath. There appeared to be no significant effect upon other forms. However, when the rate of application of the thermal aerosols was increased to about 0.5 lb. DDT per acre, significant kills of the aerial forms of a number of insects were observed, including the following: *Anopheles quadrimaculatus; Psorophora cyanescens* and *P. ferox;* Sarcophagidae; *Musca; Chironomus;* Tabanidae, Asilidae, Trypetidae, Tipulidae; Anthomyidae; Ephemeroptera; Trichoptera; *Vespa; Chrysopa;* Ichneumonidae; *Tropisternus; Donacia;* Chrysomelidae (flea beetles); and Cicadellidae. Adults of both Anisoptera and Zygoptera were abundant in the treated areas but even at dosages of 0.5 lb. DDT per acre only an occasional specimen of *Enallagma* was found to be affected.

A few preliminary observations on the effects of airplane distributed DDT dusts and sprays have been previously reported (Metcalf et al., 1945). Airplane sprays of 5% solutions of DDT in kerosene applied at rates between 0.1 and 0.25 lb. DDT per acre gave heavy kills of most forms of supra- and infraneuston, particularly the Hemiptera and Coleoptera. DDT dusts applied by airplane at similar rates gave no evidence of any injury to aquatic organisms other than mosquitoes.

In Table 2 is presented an over-all summary of the effects upon different types of macroscopic aquatic organisms of routine airplane applications of DDT thermal aerosols at the rate of approximately 0.1 lb. DDT per acre. Three types of organisms appear to be particularly susceptible, anopheline mosquito larvae, surface Hemiptera, and Dolichopodidae. The susceptibility of the latter two groups is probably explained by the fact that they "run" upon the water surface and their feet therefore come in direct contact with the flecks of DDT solution upon the surface film. It is interesting to note that gyrinid beetles which inhabit the water surface but whose swimming legs penetrate beneath the surface did not appear to be seriously affected. Culicine mosquitoes and amphipod crustaceans appeared to be moderately affected, but most other forms observed showed little or no reduction as a result of the treatments. It is interesting to note that the surface Hemiptera, the only group of macroscopic aquatic organisms in addition to mosquitoes which were seriously affected by the treatments, are predaceous and therefore probably compete with fish for food. From a consideration of the over-all data, it is concluded that the total population of fish food organisms was not significantly reduced by the routine weekly applications of DDT thermal aerosols. It should be emphasized that the summary of effects presented in Table 2 applies only to the rate and method of application indicated and does not, therefore, preclude the possibility that more serious effects might result from

TABLE 2.—A SUMMARY OF EFFECT UPON POPULATIONS OF AQUATIC ORGANISMS OF 20% DDT IN VELSICOL NR-70 APPLIED BY AIRPLANE AS THERMAL AEROSOL AT THE RATE OF APPROXIMATELY 0.1 LB. DDT PER ACRE.

Organisms	Reduction		
	None to slight (0–20%)	Moderate (21–60%)	Severe (61–100%)
I. *Aerial Forms*			
Culicidae (Diptera)	X		
Chironomidae (Diptera)	X		
Dolichopodidae (Diptera)			X
Other Diptera	X		
II. *Surface Forms (Supraneuston)*			
Hemiptera			X
Gyrinidae (Coleoptera)	X		
Araneae (Spiders)	X		
III. *Subsurface Forms (Infraneuston)*			
Anophelini (Diptera)			X
Culicini (Diptera)		X	
Hemiptera	X*		
Coleoptera	X*		
Chironomidae (Diptera)	X*		
Ceratopogonidae (Diptera)	X*		
Naididae (Oligochaeta)	X		
IV. *Climbers and Swimmers*			
Odonata	X		
Ephemeroptera	X		
Gastropoda	X		
Amphipoda		X	
Decapoda (Palaemonidae)	X		
Entomostraca	X		
Planaria	X		
Hydrachnidae	X		
V. *Bottom Dwellers*			
Anisoptera (Odonata)	X		
Ephemeroptera	X		
Chironomidae	X		

* These forms were on the borderline, and further study might reveal that at least certain species should be placed in the moderate reduction group.

higher dosages or different methods of application.

EFFECTS UPON FISH

Observations of natural fish populations in areas exposed to a full season of DDT treatment were made in the Sweetwater and Whiteside Bays of Wheeler Reservoir. Each of these areas is connected with the main reservoir by a narrow ditch, which facilitated diking them off to prevent fish from entering or leaving. The Whiteside area contains a heavy growth of American lotus (*Nelumbo pentapetala*) and watershield (*Brasenia schreberi*) in the deeper water portions and has a total area of about six acres at top pool level. The Sweetwater area has only normal marginal vegetation with open water in the center. Its top pool area was about 17.5 acres and it gradually receded during the summer to an area of ten acres in the latter part of September just before

the fish population was measured. Both areas received weekly airplane applications of DDT thermal aerosols at the rate of 0.1 lb. DDT per acre from May 29 to September 11, inclusive, making a total of 16 treatments with a cumulative dosage of 1.6 lbs. DDT per acre.

TABLE 3.—SUMMARY OF FISH POPULATION IN SWEETWATER BAY OF WHEELER RESERVOIR SEPT. 26–27, FOLLOWING SIXTEEN WEEKLY TREATMENTS WITH DDT THERMAL AEROSOLS DISTRIBUTED BY AIRPLANE AT THE RATE OF 0.1 LB. DDT PER ACRE.

Species	Amount per acre of water surface	
	Number	Weight in pounds
Rough Fish	*1,030*	*551*
Shad (*Dorosoma cepedianum*)	543	137
Buffalo (*Megastomatobus cyprinella & Ictiobus bubalus*)	45	79
Carp (*Cyprinus carpio*)	403	283
Shortnosed Gar (*Lepisosteus productus*)	35	49
Other	4	3
Food Fish	*117*	*38*
Channel Cat (*Ictalurus furcatus*)	2	5
Bullheads (*Ameiurus* spp.)	97	23
Drum (*Aplodinotus grunniens*)	18	10
Game and Pan Fish	*652*	*62*
Largemouth Bass (*Huro salmoides*)	13	13
White Bass (*Lepibema chrysops*)	40	6
Bluegill (*Lepomis machrochirus machrochirus*)	471	26
Black Crappie (*Pomoxis nigro-maculatus*)	41	9
White Crappie (*Pomoxis annularis*)	87	8
Small Fish (Mostly Young-Of-The-Year)	*10,750*	*49*
Centrarchidae (mostly bluegills)	10,000	45
White Bass	750	4
GRAND TOTALS (exclusive of small fish)	1,799	651
GRAND TOTALS (including small fish)	12,549	700

The fish population in the Sweetwater area was measured on September 26–27, about 2 weeks after the last treatment with DDT (Plate I). All of the large fish were collected and weighed, but it was impossible to collect the many thousands of small fish 1 to 3 inches in length which were present in the area. These young-of-the-year were mostly bluegills, but white crappie were also abundant, and white bass, bullheads, and largemouth bass were common. The estimate of the total population of small fish was made by counting the dead along representative sections of shoreline and weighing samples. The estimate is considered too low, since many of the fish undoubtedly did not drift to shore. *Gambusia* were also very abundant in the area but since they sank soon after treatment and did not float again as did most species, it was impossible to make representative counts. From previous experience in population studies, it is estimated that

the area contained an average of at least 20,000 *Gambusia* per acre.

A summary of the results of the fish population study in Sweetwater bay is given in Table 3. The average of 12,549 fish (exclusive of *Gambusia*) and 700 lbs. per acre compares favorably with data obtained by Tarzwell (1942) from five areas of Wheeler Reservoir, his average being 10,141 fish and 311 lbs. per acre. In fact, the population of 700 lbs. of fish per acre approaches the the maximum of 831 lbs. which he found in one of the five areas. The species composition of the fish population also compares closely with Tarzwell's data. He found the per cent composition by weight of the various types of fish to be as follows: rough fish, 82.5%; game fish, 3%; pan fish, 9.6%; and food fish, 4.9%. In the present studies these percentages (exclusive of young-of-the-year) were as follows: rough fish, 84.7%; game fish, 2.9%; pan fish, 6.6%; and food fish, 5.8%.

Determinations of the condition (K)[3] were made for five species for which comparative data were available from specimens collected in Wheeler and Chickamauga Reservoirs. The results are shown in Table 4. It will be observed that there was no indication of any significant differences in the fish from Sweetwater Bay which had been exposed to a full season of treatment with DDT and those from untreated areas of Wheeler and Chickamauga Reservoirs.

From a consideration of the total numbers and weight, the species composition, the condition, and the abundance of young-of-the-year, there is no evidence that the sixteen applications of DDT thermal aerosols in any way injured the fish population in Sweetwater Bay.

Because of the abundance of lotus and watershield in the Whiteside area, it

TABLE 4.—AVERAGE CONDITION (K) OF FISH COLLECTED FROM SWEETWATER BAY AFTER FULL SEASON OF TREATMENT WITH DDT AS COMPARED WITH FISH COLLECTED FROM SIMILAR UNTREATED AREAS OF WHEELER AND CHICKAMAUGA RESERVOIRS.

Species	Length range of Sweetwater fish	Condition (K) of fish	
		Sweetwater (Treated)	Main reservoir (Untreated)*
Largemouth Bass	4–20 inches	2.5	2.4
White Bass	4–16 inches	2.4	2.3
Black Crappie	4–12 inches	3.0	3.0
White Crappie	4–12 inches	2.7	2.6
Drum	8–16 inches	2.3	2.3

* Data for white bass are for two-year-old fish from Wheeler Reservoir (Howell, 1945). For other species the data are for two-year-old fish from Chickamauga Reservoir (Eschmeyer et al., 1944), information on (K) for these species not being available for Wheeler Reservoir.

[3] The value of K is determined by the weight-length relationships of the fish, higher values indicating greater weight in proportion to length. The formula for deriving K and its value for a number of species of fish collected from Tennessee Valley reservoirs has been recently given by Eschmeyer et al., (1944).

Collecting, weighing, and measuring fish from the Sweetwater area of Wheeler Reservoir, September 27, 1945. The light boat facilitated the picking up and transportation of the dead fish. Note also the measuring board on the table in the background and the scale mounted on a frame to facilitate weighing the larger fish.

was impracticable to determine the fish population for the entire area at the end of the season. However, representative sections were treated and numbers, species composition, and condition of the fish appeared to be similar to the fish population in Sweetwater area. For example, one small isolated pool with an area of only a fraction of an acre contained well over 200 lbs. of fish including largemouth bass, bluegills, shad, buffalo, carp, and gar.

SUMMARY AND CONCLUSIONS

Investigations were carried out in the Wheeler and Kentucky Reservoir areas of the Tennessee Valley during the summer of 1945 to determine the effect upon fish and fish food organisms of a formulation of 20% DDT in Velsicol NR-70 applied by airplane in the form of a thermal aerosol at the rate of 0.1 lb. DDT per acre with an average maximum recovery in the center of the swath of about 0.012 lb. per acre. The maximum effect at the center of the swath resulted in almost complete elimination of anopheline and culicine mosquitoes and surface Hemiptera and in a significant reduction in Coleoptera and amphipod crustacea with little or no reduction of other macroscopic forms. The effect of routine treatments on an area basis was almost a complete elimination of anopheline mosquitoes and surface Hemiptera and a significant reduction in culicine mosquitoes with no evidence of reduction of other forms. Observations in areas at the end of a full season of 16 applications at the rate of 0.1 lb. DDT per acre indicated that surface Hemiptera had been almost completely eliminated and mosquitoes were considerably reduced but other forms were not significantly affected. Surface Hemiptera are not important as fish food and because of their predaceous habits may actually compete with fish for food. On the basis of these studies, it is therefore concluded that DDT applied in the manner indicated does not have any significant injurious effect upon the total population of fish food organisms.

Determination of fish populations at the end of the season in areas which had received 16 routine weekly applications of DDT thermal aerosols at the rate of 0.1 lb. DDT per acre showed an average population per acre of 12,549 fish weighing 700 lbs. From a consideration of the total number and weight, the species composition, the abundance of young-of-the-year, and the condition of the fish in comparison with those in untreated portions of the reservoirs, it is concluded that the DDT treatment had no injurious effect upon the resident fish population.

It is emphasized that the above conclusions apply only to this dosage and method of applying DDT and do not mean that increased rates of application or different methods of application might not have injurious effect upon fish and fish food organisms.

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HELL'S GATE AND THE SOCKEYE[1]

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The first Bulletin of the International Pacific Salmon Fisheries Commission (Thompson, 1945), which appeared recently, is devoted to an analysis of a question which for many years has been hotly discussed in Pacific Coast fishery and conservation circles. The canyon of the Fraser has long been considered a difficult part of the migration journey for the salmon of that river. Within the canyon, some reaches are narrower and swifter than others; the narrow gap of Hell's Gate seems to present the greatest obstacle. Even before the white man had modified the river in any way the Indians congregated there in great numbers to fish, as old accounts and photographs testify. Whether in those days the Gate caused anything more than a delay of an hour or so in the average time of passage of the fish, cannot now be ascertained. The first important indication that the canyon might be seriously impeding the run of salmon in the river came in 1913, when very large numbers of sockeyes were apparently held up on their journey. Many matured in the river above and below Hell's Gate, or were crowded into small tributary streams which normally did not hold sockeye at all. Construction of the Canadian Northern Railway on the south and east bank of the canyon had just been completed (1911–12), and much rock had been dumped into the the river at various places. Reports for 1913 place less emphasis on Hell's Gate, as an obstruction, than on several other rapid places. Early in 1914 however a large slide of rock entered the river just above the Gate, and the continuing obstruction in 1914 was largely blamed on that site. During the winter of 1914–15 much rock was taken out of the river at the site of the slide, and the other apparent obstructions had also been cleared, so that by 1915 the river was pronounced clear, or at least as good as

[1] Contribution no. 323 from the Department of Zoology, Indiana University.

it ever was. This apparently has remained the official view ever since. It is notorious, however, that many of the runs of salmon above the canyon have remained much less numerous than formerly, and reports from the canyon have suggested, from time to time, that things might not always be for the best. The local Fishery Guardian and various special observers at the Gate have reported that fish could be seen accumulated below the Gate, in varying numbers, throughout the summer and autumn; that some water levels seemed more "difficult" than others, judging by the size of these accumulations; that many such fish took on the spawning color; and that the small creeks below the Gate contained these "blocked" fish in appreciable numbers in some years. At the same time it was observed that *some* upriver sockeye runs, notably those to Chilko Lake and Adams River, increased greatly during this period, apparently bearing out the official view that, for them at least, the canyon offered no serious obstacle.

When the Salmon Commission began work in 1938, it was obvious that any serious attempt to resolve the conflict of opinion regarding the passability of Hell's Gate, and the canyon in general, meant solving the following problems:

(1) At what water levels, if any, are salmon noticeably obstructed by the Gate?

(2) How complete is the obstruction at these levels—*i.e.*, what fraction of newly-arriving fish get through at each level without delay sufficient to impair their reproductive value?

(3) How long do such levels last in different years?

(4) What eventually happens to fish temporarily or permanently blocked?

(5) What runs (races) of sockeye are most affected?

There can be no doubt concerning the practical importance of these questions. The answers suggested in the new Bulletin have been the principal public justification for the recent construction of fishways which have cost a rather large sum of money. Briefly, the conclusions reached are that fish were blocked at the Gate when the water was at certain definite levels, which at times lasted for weeks without interruption; that while a few fish got through during such a block, the fraction did not exceed 20 per cent and may have been much less; and that this stoppage has been a major cause of mortality in the years since 1915, though varying greatly from year to year.

It is too late to influence the question of the fishways, but reexamination of the factual basis for these conclusions is still of first-rate importance because of the influence they may have on the future activities of the Commission, and hence on the Fraser sockeye runs. It is our hope too that the questions to be raised will be helpful in planning similar studies in future, on the Fraser or elsewhere.

A critic's role is always an invidious one, so before proceeding to discuss what seem to be its questionable aspects, we wish to emphasize that Dr. Thompson's work is a storehouse of useful information concerning sockeye migration, based on six years of observation and experiment, and illustrated throughout by an adequate, or even lavish, series of diagrams. From one point of view, however, it is precisely this abundance of factual material

which makes a critical analysis particularly urgent. In any report involving a large body of data, no matter how conscientiously prepared, the lay reader tends to be overwhelmed by details and to confound the facts and their interpretation. Under such circumstances the conclusions reached by the author tend to acquire a specious validity simply from their physical proximity to so great a mass of evidence, and independent of their intrinsic merit.

In the work at hand it appears that, of the questions listed above, good answers have been obtained for (1) and hence also (3), and that an important and valuable body of data is available concerning (4) and (5). Unfortunately, on the crucial question of the actual fraction of fish stopped, the facts presented seem incapable of giving any definite information.

TAGGING AT HELL'S GATE

The reason for failure to obtain all the necessary information can be stated very briefly. The greater part of the conclusions in the Bulletin are derived from recaptures of fish caught and tagged just below Hell's Gate. We may hypothesize that, at any given water level, some newly-arriving fish go through the Gate rapidly, but others are impeded for a certain time. The blocked fish accumulate in the eddies below the Gate, and may constitute a very much larger fraction of the fish available for capture there, than of the total run upriver. Thus the tagging is done on what may be a highly-selected group of fish, among which weaklings greatly predominate. It is enough that the published analysis does not *exclude* this hypothesis, in order to make its conclusions questionable. Actually, however, this appears to be a very natural and obvious view, which is strongly suggested simply by the appearance of the fish taken at the Gate: during August and September, at least, they include far more individuals with advanced breeding colors, battered noses, etc., than are found among Indian catches taken a few miles either above or below.

A second weakness of the analysis is also evident. After being caught, tagged and released, a salmon is not necessarily the same fish as just before. The experience may make the fish disinclined to continue upstream immediately, and in fact the tag recoveries indicate that tagged sockeye leave the Gate and do not return for several days. More serious than that, the fish may be physically weakened, perhaps not so much by the tag itself as by a common accident of catching: the splitting of the tail fin by the net. With a crucial test of swimming ability immediately ahead, the split tail may well be a serious handicap to a salmon, and responsible for much of the failure of the tagged fish to proceed upstream within a short time.

Since neither of the above possible sources of error is mentioned in the report, it must be assumed that neither has been critically examined. This is the more unfortunate because both had been recognized during the first year of tagging, and the problem of obtaining data on their quantitative effect appears to present no insuperable difficulty. Information on one of the effects of handling the salmon might be obtained simply by taking notes on the condition of the tail fin of all fish tagged. Comparisons of percentage recoveries between fish with the fin split once,

twice, thrice, or not at all, would shed valuable light on the reality or otherwise of this possible handicap. Or if doubts concerning possible injurious effects of the tag itself were entertained, they could have been resolved by tagging some "control" fish on the jaw, where the chance of injury seems remote.

To ascertain the possible effect of selection of weak fish accumulated at the Gate, a complete answer would be obtained only by transfering the tagging station some distance downriver, to wherever such selection would be inconsequential. The possibility of taking fish for tagging, using commercial gear above the commercial fishing limit on the river, was discussed almost from the beginning of the Commission's existence, and while it may present difficulty there is no mention of its having been seriously explored. Some information on this question might be gained even from the tagging at Hell's Gate, by comparing the recaptures of fresh green fish with those of the more mature or battered ones, during each week of tagging—on the assumption that the latter were "blocked" fish. However there would be intermediate specimens, and the precision of this method would perhaps not be great.

With regard to the possible magnitudes of the effects of the above two sources of error, it can be said without hesitation that they *may* be sufficient to completely invalidate the conclusion that the Gate has been (1938–42) a serious obstacle to migration. Throughout the water-levels at which salmon are said to be "blocked," *some* tagged fish do get through. The number, according to the report (p. 138), may be up to 20 per cent of the number which pass through when there is no block. This situation could be completely explained on the following basis. Suppose that during the block 90 per cent of the newly-arrived fish get through immediately, leaving 10 per cent below the Gate. This 10 per cent accumulates rapidly; they are available for capture every day and all day for a period of up to several weeks, whereas the fresh-run fish may be available only an hour or less. Under these circumstances, it is quite probable that those tagged would consist of 80 per cent or more of blocked fish and only 20 per cent or less of fresh fish. Ninety per cent of the latter, but only 18 per cent or less of the total tagged, would get through to the upper river.

In the absence of factual information, the above percentages can be juggled almost at will, and hence all the observed tagging results are completely explicable on the basis that the Gate is always immediately passable to 90 per cent or more of the newly-arriving sockeye. We can even take the view that the hypothesis presented here is a likely one, and hence that if even as few as 5 per cent of the *tagged* fish get through immediately, many times that percentage of freshly-arrived fish probably do the same. No mention is made of possible effects of tag or net damage in the above, but obviously, if such damage exists, it makes tagged fish even less likely to pass the Gate, and reinforces the argument.

ENUMERATION OF BLOCKED SOCKEYE

There is one other possible direct method by which an estimate of the number of fish blocked might be ob-

tained, namely by enumerating the fish which die below the Gate. This subject is not considered in the recent Bulletin. It is dismissed with the remark that it "presents difficulty," which is certainly no overstatement. However in the Commission's 1941 annual report (Thompson, 1943) some tentative figures are quoted for that year, which was the one in which the most serious stoppage of recent years occured; conditions then are even said to have been "strikingly similar" to those of 1913. It is stated that the number of fish which failed to pass Hell's Gate in 1941 was estimated as one-half to two-thirds of the total: also that some observers estimated "over a million" fish died.

Until the basis for these estimates has been reported, it is necessary to reserve judgment concerning their value. One may venture a guess that the number of dead salmon actually seen did not exceed 20,000 or so, and it is difficult to picture what plan has been used to arrive at the larger figure. Even up to 50,000 sockeye killed would represent only about 10 per cent of the estimated 1941 escapement beyond Hell's Gate, and hence could not be regarded as serious unless it were concentrated on races of fish now critically depleted. Such, however, is not the case. From the tagging results, it appears that the important depleted runs are mostly early and largely went through the Gate *before* the time of the long blockade. Two of these early races—Stuart Lake and Quesnel—had in 1941 much the largest spawning population of recent years (through 1944). From the timing of the 1941 block, and the tag recoveries obtained, it is evident that most of the fish affected belonged to the large Chilko Lake run of that year, of which no less than 464,000 are estimated to have reached the spawning grounds.

HELL'S GATE WATER LEVELS AND THE COMMERCIAL CATCH

It appears therefore that investigations to date can give no direct answer to the vital question of what percentage of the sockeye are actually blocked by the Gate. Then can an answer be supplied indirectly? In this connection section III-F of the recent Bulletin must be carefully considered, for it is devoted to demonstrating a relationship between the number of days of favorable water levels at Hell's Gate in September and October, and the success of reproduction of the Fraser sockeye as a whole. The latter is measured by means of the index "C_4/C_0," i.e. the catch during the year of observation divided into the catch 4 years later. This index is compared with the number of days of favorable water levels in Figure 56 of the Bulletin, and also, in a double logarithmic presentation, in Figure 58. Another possible relationship, that between the logarithm of C_4/C_0 and the number of days favorable for passage, is plotted here as Figure 1. In all these diagrams some association is evident between the two series of variables, but it is always very inexact. In Figure 1, the best regression line has a slope of 0.00684 log units per day, corresponding to an increase of 17 per cent in C_4/C_0, over its previous level, for each additional 10 days of favorable water. The standard deviation of the points from the regression line is 0.190 log units. Taking the conventional $\pm 2\sigma$ as a measure of the likely range of deviation, this means, for example, that when the most

probable value of C_4/C_0 is 100 per cent (as estimated from the water levels), values as low as 42 per cent or as high as 240 per cent will be encountered not too infrequently. Other simple types of relationship between water levels and C_4/C_0 yield standard deviations comparable to the above. In spite of this, there are data for enough years to make the reality of the relationship beyond reasonable question. In our Figure 1 the regression coefficient is 2.63 times its standard error, and Dr. Thompson quotes similar figures obtained by other methods.

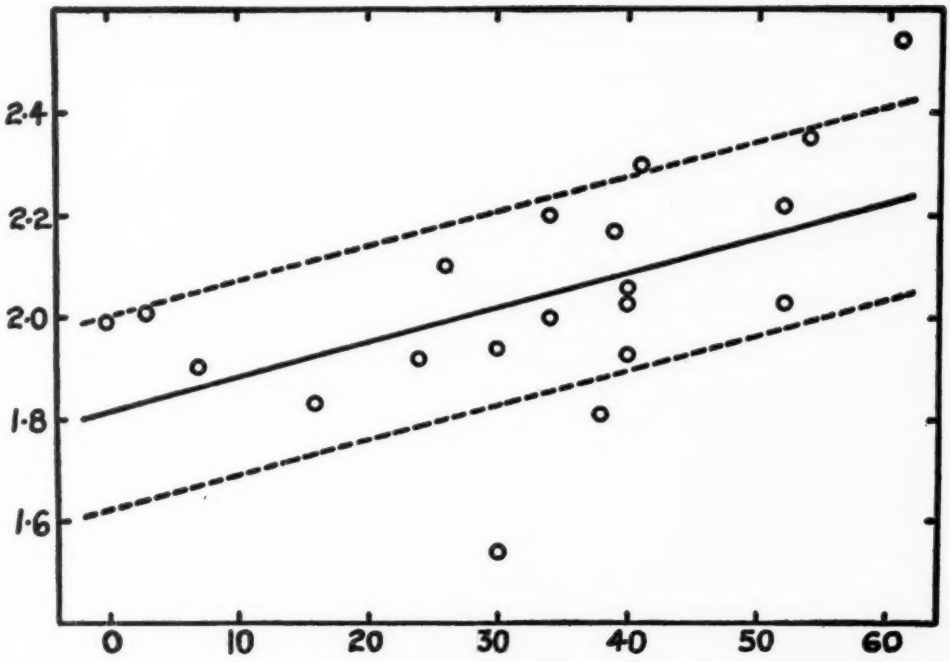

FIG. 1.—Relationship between the number of days favorable for passage in September and October (abcissa), and the logarithm of the index 100 C_4/C_0 (ordinate), from 1920 to 1939 inclusive. The solid line is the best linear relationship between the two, and the dotted lines mark the limits of the standard deviation. Data from Thompson (1945).

Nevertheless we are still far from knowing whether the Gate has any effect upon migration and reproduction. Granting that a real relationship between water stages and the average success of reproduction is probable, it does not necessarily follow that the former directly affect the latter. A *causal* connection is still wholly an assumption, and cannot be taken for granted. The Hell's Gate water levels are not an isolated and independent phenomenon; rather they are related to the weather over the watershed, and in particular to the rainfall. The favorable water levels in September and October are below a guage level of 26 feet, and at that season low water means average or less-than-average rainfall upriver; for

water from melting snow and ice, which during the summer is important, has by autumn been greatly reduced. Obviously a thing as universal as the weather might affect the sockeye in a number of ways, either during their migration or on their spawning grounds. To cite what may be the most likely alternative suggestion, excess rainfall may decrease the efficiency of reproduction by floods scouring the spawning beds, and at the same time raise the water level in the river. In that event the observed correlation between water levels and the C_4/C_0 index could exist in the complete absence of any difficulty of passage through the Gate. Other less likely suggestions for causal relationships might be offered, for example a possible relation of commercial fishing or Indian fishing to the weather or to the river height; investigation of all such possibilities might be a complex task. Meantime it must be insisted that again no proof has been obtained that Hell's Gate has been any serious obstacle to migration in recent years.

The argument above can be pushed even further. Even making allowance for the unavoidable crudeness of the C_4/C_0 index as an estimate of success of migration and reproduction, if the water levels are actually a major factor of influence, there seemingly should be a closer correspondence between the two than actually exists. On this view the large deviations of the individual years from the average relationship suggest that for the causal agent we should look not to the water level itself, but rather to some factor correlated with water level, but not *too closely* correlated. A suggestion of uneasiness on this score can be detected in the recent Bulletin, for an effort is made to improve the apparent relationship by an appeal to different "trends" at 4-year intervals over the years concerned (Fig. 57). But the separation of the years into groups of four in this figure is wholly arbitrary. There is no reason why the years 1920–23, 1924–27, 1928–31, 1932–35, and 1936–39 should have been associated together, instead of 1922–25, 1926–29, 1930–33 and 1934–37 for example; and if the latter system is followed the apparent improvement in fit to individual regression lines disappears completely. For that matter, even as they are plotted the improved fit shows up in only the first two of the five groups of years first listed above.

ANALYSIS OF SEX RATIOS

Another possible indirect line of evidence bearing on the escapement through Hell's Gate, of which no analysis has yet been published, is a study of the sex ratios of the sockeye found in different places. It will be worth while to consider this briefly. There is much evidence, from the Fraser watershed and elsewhere, that male salmon are better able to surmount barriers than females. For example, it was observed in the canyon in 1913 that the blocked sockeye were predominantly females. In the report on the spawning beds of the Fraser in that year (Babcock, 1914), it is mentioned that Spuzzum Creek, below the Gate, was filled with blocked sockeyes, among which there were 20 females to one male. As reported to the writer by Alexander Robertson, who then was personally engaged in the salvaging of eggs from the river, he and other spawn-takers could "sit on the bank and pick females up all day long in

our gloved hand, but to get enough milt we had to gaff individual males here and there; it kept one man busy looking for males." (It will be recalled that one male is sufficient to fertilize the eggs of many females.) This preponderance of females among blocked sockeye has continued down to the present, although in recent years the sex ratios have usually been less disproportionate. A marked excess of females has been reported rather consistently throughout the years, among the blocked fish which appear in the small canyon creeks. The writer observed sex ratios of approximately 1 male to 3 females in Spuzzum Creek during 1938. In the Commission's annual report for 1942, the proportion 27 per cent males and 73 per cent females is given for such creeks.

Corresponding to this surplus of females in the canyon, there should of course be a surplus of males on the upriver spawning grounds whenever the number of blocked fish is large enough to be an important fraction of the total run, because observations on sockeye taken in the ocean fishery show that there the two sexes are almost equal in numbers. Unfortunately, in published records concerning 1913 and the years following no mention appears to be made of the sex ratio of the sockeye which reached upriver tributaries. Probably this information could still be obtained from eye-witnesses, or from contemporary records. However, since there is a general agreement that a very important part of the 1913 run was blocked and that these blocked fish were predominantly female, it almost necessarily follows that there was a corresponding surplus of males on the spawning grounds above.

Returning now to the blockade of 1941, we should expect that if the fraction of the run blocked was as large as the one-half or two-thirds suggested in the annual report for that year, and if these blocked fish included a substantial surplus of females, then there should inevitably be a corresponding surplus of males on some of the upriver spawning beds. Perusal of the reports on these beds shows however that the proportion of males was estimated as from 33 to 58 per cent in various places, the average being something *less* than 50 per cent. At Chilko Lake, whose run dwarfed all others in 1941, and was passing through the canyon at the time of the block, the proportion of males is given as 49.8 per cent. It might be argued that males may be for some reason less susceptible to enumeration on the spawning grounds, or may be caught more frequently by Indian fishermen above Hell's Gate; so that a 50:50 ratio on the redds would imply an excess of males passing the Gate. These variables can be controlled by means of a comparison with the year 1942, when the Gate was not blocked at all during September and October. In that year the upriver runs included males to the extent of from 36 to 50 per cent, the figure for Chilko Lake being 50.0 per cent, almost exactly the same as in 1941. Thus there is very good evidence that no unusual surplus of males passed through the Gate in 1941. In that event the stock blocked below the Gate, which almost certainly included a substantial surplus of females, could not have constituted any very large part of the total migrants. If the argument is sound, the logical conclusion is that the stoppage of 1941 destroyed only an unimportant fraction of the

fish which reached the Gate.[2]

It should not be considered that the sex ratios constitute a complete proof that Hell's Gate has been wrongly accused of obstructionism. However they do seem to be the least equivocal evidence which is currently available on the subject, and the facts adduced must be considered and explained in any future hypothesis which is to be acceptable. A weakness is of course the fact that there is no information published concerning the sex ratio among the blocked fish of 1941, so that the assumption that females predominated has yet to be checked. Undoubtedly this can be quickly done from the Commission's records. However if in 1941, contrary to all earlier and later experience, the two sexes were present among the blocked fish in more or less equal numbers, then whatever the conditions in the canyon may have been, they certainly did not resemble those of 1913!

FUTURE PLANS

By now of course the question of whether Hell's Gate was or was not an important obstacle to migration has become largely academic. The Canadian and United States governments have completed new fishways surmounting the difficult water, at a cost said to be about $2,000,000. Earlier proposals to take similar action were held up partly by the fear that more harm than good might be done. The sum finally made available for the project should insure that the new ways are adequate, or at any rate not deleterious. No doubt tests have been made or will be made at the Gate to determine whether or not blocked fish can still be taken at the critical water levels, and, more important, to discover what fraction of the migrating salmon actually use the fishways instead of the river channel itself. However, there will be no proof that the new structures are really useful unless it can be demonstrated that they permit upriver sockeye runs to increase more rapidly than has hitherto been the case. It must be emphasized that the currently important upriver runs—Chilko Lake and Adams River—have increased during the last 25 years to many times their abundance prior to 1920, in spite of any possible obstruction in the canyon during that period. Other upriver runs have apparently shown much less striking increases during that time—including those to the Stuart Lake region, Quesnel Lake, most of the Shuswap Lake tributaries, and so on—though in some cycle years encouraging gains have been reported. If all these runs consistently show outstanding improvement in the immediate future, without aid from other conservation measures, the fishways will have justified themselves.

The question is, should we take time to wait and see? These remnants of the once-abundant early runs are quite literally worth their weight in gold. They are the nucleus from which the size of the Fraser sockeye catch can be trebled or quadrupled, at the most conservative estimate. If completely lost, it might prove an extremely difficult or impossible task to restore them. Should we hesitate any longer to grant them the benefit of a completely closed fishing season, say to the middle of August in each year? Desirable as it would be,

[2] We are excluding of course the unlikely eventuality that the blocked fish were heading for some spawning ground as yet unknown.

scientifically, to test the new fishways without taking additional steps in conservation for a period of 8 or 12 years, that is a luxury which we simply cannot afford. Particularly is this true when the analysis of sex ratios suggests that the Gate has never been an important obstruction in recent years, while the evidence advanced for the contrary view is at the best inconclusive, and can even be considered to point in the other direction. If the Gate has not been a serious obstruction recently, then the new fishways will be little or no improvement over the former state of affairs. In that event the only immediately practical way to improve early upriver runs more rapidly will be to lighten the fishing load which they bear. Dr. Thompson estimates the commercial fishery may take about 80 per cent of the sockeye returning from the sea; and tag returns show that 50 per cent is the absolute minimum. At that rate closure of the early fishery would increase the early spawners upstream two-fold to five-fold, and the regeneration of badly-depleted areas would be tremendously accelerated. Since the sockeye catch taken prior to August 16 normally amounts to only a rather small percentage of the total, its loss would be a negligible temporary sacrifice compared to the prospect of abundant future gains.[3]

Although from the biological point of view the construction of the fishways has been strictly a gamble, this does not necessarily mean that the project was unwise. Other considerations, and important ones, may have entered into the decision, and the writer is in no position to know what they all were, much less evaluate them. For example, sooner or later a battle must be fought out between the fishing industry and those who wish to develop hydroelectric power on the Fraser. When that day arrives, it will probably be the actual yearly salmon production which will be thrown into the balance to offset the claims of the power interests, rather than nebulous future production possibilities. With these fateful decisions looming up in the not too distant future, it can be argued that any project is completely justifiable which might conceivably be of some important benefit to the salmon, even though the likelihood may appear rather remote. Furthermore, the very fact that a large investment has been made in fishways for upriver salmon runs can itself serve as a measure of their importance, in future debates, and may make legislators less likely to sanction acts that would prejudice their existence. Such arguments may be good or bad; we mention them only as examples of the kinds of considerations which *may* have been involved when the decision to build the fishways was made. It follows that nothing in this paper should be construed as implying a criticism of their construction—that subject is not under discussion here. Our concern has been merely to evaluate the available data

[3] The exact opening date could be varied from year to year, depending on the time of appearance of the main body of commercial fish. In 1946 the Commission has taken a step in the right direction by closing the Fraser River fishing up to August 8, with earlier opening dates for areas at various distances from the river. However in 1946 the bulk of the fish were not expected and did not appear until September, so that an opportunity to extend complete protection to all the fish of early runs presented itself, and was to a large extent lost.

bearing on the effects of the Gate on the sockeye runs before the fishways were constructed.

CONCLUSION

In conclusion, it is perhaps in order to mention that the writer's first impressions were *for* rather than *against* the proposition that Hell's Gate has been a serious obstacle to migration. He was a member of the Salmon Commission's canyon party of 1938, which confirmed by tagging what had long been believed by observers like Fishery Guardian Scott of Hope—namely that salmon accumulate below the Gate at certain water levels, and largely disappear upstream when the water falls below about 25 feet on the guage. We regarded this "discovery" as of tremendous possible importance, but since no analysis has been made of its inherent errors, its significance remains conjectural to this day. In any event, now that the new fishways have begun to pass salmon up the river, the Gate can be forgotten and attention focussed on other pressing problems of sockeye conservation. In addition to the immediately practical problem of providing protection for adult fish of depleted runs, these include, for example, the problem of finding what conditions are necessary for successful transplantation of stocks, information which will be necesssary when runs now exterminated are to be rehabilitated, or when now-inaccessible lakes are opened to sockeye; and also the problem of what determines the maximum migrant production from each lake, and what measures can be taken to achieve it. These urgent questions and others have largely been shelved during the last eight years, pending a solution of the Hell's Gate problem. While that problem certainly cannot be said to have been solved, it is at least closed, and from now on will no longer be a distraction. Perhaps that in itself is worth $2,000,000. The danger is that fishermen and conservationists may be tempted to feel that a major improvement has been effected, and that now we may relax our vigilance. There is no basis for such optimism; in particular, the desirability of complete protection for the valuable early-run fish is as great as ever, and should no longer be withheld.

SUMMARY

A review of published information indicates that there is no unequivocal evidence for the view that Hell's Gate on the Fraser River has blocked any serious fraction of the sockeye salmon run reaching that point in recent years. Sex ratios observed among sockeye taken above and below the Gate *suggest* that the fraction blocked, in even the worst years, was in reality quite small—probably less than 10 per cent.

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CANADA GOOSE MANAGEMENT, SENEY NATIONAL WILDLIFE REFUGE

C. S. Johnson

Seney National Wildlife Refuge, Germfask, Michigan

A cherished hope of persons associated with establishment of the Seney National Wildlife Refuge, Schoolcraft Co., Michigan, was that the Canada Goose (*Branta canadensis*) eventually could be induced to nest there; with a breeding colony now established it seems that this has been realized.

Located in the Seney Marshes of the Upper Peninsula, a scene of drastic timber cutting and ill-advised drainage early in this century, the Refuge today exemplifies what can be accomplished when the assistance of Nature is enlisted in wise use of the land. The expansive marshes again provide ideal habitats for many species of ducks and other wildlife as well as the backdrop to the Canada Goose experiment which culminated so successfully.

While the Refuge was still in early developmental stages, the experiment was launched on a sub-zero day late in January 1936 with 300 birds donated by Mr. Henry Wallace of Detroit, Michigan. The intense cold and the presence of coyotes and other predators on the refuge and nearby made confinement of the geese necessary. A 2-acre holding pen with a small water hole within the lee of a wooded hill was prepared and they remained there until spring. About 10,500 pounds of mixed grain, chopped alfalfa, oyster grit, and egg mash were fed. Some loss within such small quarters was inevitable and 14 died. As the breeding season approached, the birds became more aggressive and much fighting ensued; 22 geese finally escaped through the fence to the open marshes where at least five pairs nested. A camp foreman brought in the young of one pair, and when attempts to return them to the parents failed, they were kept at refuge headquarters but only one was raised. Fourteen young were counted in the remaining four broods, but since they were at large in the marshes their fates were not known; however, numerous reports of the unusual observations of Canada Geese well down the Manistique River that autumn indicated the young were held to the locality by the pinioned parents.

Development of a permanent 400-acre pasture for the birds was started in the spring of 1936, and the remaining birds transferred to a 40-acre section on April 25; several tried unsuccessfully to nest. By autumn the fence was completed around the 400 acres which included three pools impounded by dikes; with the upland and marsh areas then in the enlarged pasture the geese were provided with good living quarters, as evinced by small winter loss in 1936–37, despite a rigorous season. Natural foods were supplemented during this second winter with a mixture of corn, barley and oats and as the 1937 breeding season drew near, egg mash and wheat sprouts were added to the diet to increase egg fertility.

Just before the 1937 nesting season,

26 pairs of geese were released into the completed pools near headquarters, to reduce competition for nesting sites within the goose enclosure and to serve as a check on nesting there. Later observations revealed satisfactory nesting in the pool areas, and 23 nests in the goose pasture. The refuge manager estimated at least 50 young reached flying age in 1937.

By the beginning of the 1938 season the original flock was reduced to 262 birds, but improved water conditions in that year were reflected in the increase of nesting within the pen, 51 nests being found within the enclosure. Sixteen young were raised by four pairs of pinioned birds at the headquarters pool where geese were released to test the value of food in holding them to a given area. Nineteen other young were seen on the open marshes, the progeny of birds nesting freely about the refuge water areas. In all not less than 95 young were produced on the refuge in 1938. Loss of goslings within the goose pen was very high, being attributed chiefly to fighting among the adults and separation of small young from their parents while enroute through the tall grass from their nests to water. On several occasions adult birds or pairs were seen leading 14 to 22 young obviously combinations of several broods or groups of strays.

The year 1939 was not a good one for the Canada Geese; there were 62 nests in the goose pen but the cold wet spring reduced production below that of the previous year. Optimum conditions prevailed in 1940. Previous development work had disturbed the nesting geese, especially shrub and tree clearance from parts of the goose pasture destined to increase the feeding areas and improve nesting conditions. Better control of water levels on the refuge was possible in 1940 as the dikes were completed. Seventy nests were counted in the goose pasture and a total of 123 goslings banded. At least 25 additional young were raised at large on the refuge marshes.

Steadily improving conditions within the goose pasture continued in 1941; fewer nests were located (60), yet 131 young were banded from them. General observations indicated increased nesting over the refuge marshes and pools but the extensive nesting habitat developed by the restored marshes within the area made any really accurate estimate of production outside the goose pen quite impossible with the limited personnel.

The reduction in nesting within the goose pen noted in 1941 was more obvious in 1942; more important was the increasing numbers of young geese being produced over the refuge at large. With a skeleton force under wartime restrictions only 79 young and 16 young fliers were banded this year, although it was conservatively estimated that at least 200 geese were produced within the pen and on nearby refuge marshes. An additional 25 per cent could safely be added for those produced on outlying marshes of the refuge. When the pinioned birds were corralled in December 1942, only 160 could be accounted for.

High waters during the spring of 1943 resulted in poor nesting both within the enclosure and about the refuge marshes, with fewer young reaching the flying stage than in the previous season.

A check of the pinioned geese just previous to the 1944 breeding season

showed that only 100 remained of the original flock. Twenty-six nests were located in the goose pen where a high nesting success was noted; 103 young were produced in the pasture and at least 62 in Unit 1, an excellent nesting area, and a similar number in Units 2 and 3. Accurate count of the wide marshes of the refuge was impossible and these figures are purposely conservative.

The increased use of the refuge during the 1944 autumn migration period was most noticeable; an estimated 1,200 geese rested for varying intervals within the refuge pool areas.

The success of the experiment seemed assured in the spring of 1945, when only 45 of the original flock were left to nest; but Canada geese then were common on all water areas of the refuge and on many nearby marshes of the Upper Peninsula. Following the breeding season, immature birds were common on these areas. Late in October 1945, when feeding of the refuge geese began previous to their return to the goose pen for the winter, 1,120 were counted on the feeding areas. These undoubtedly were refuge bred geese as exhibited by their fearlessness of the refuge personnel and readiness with which they fed with the pinioned birds. Approximately 2,000 "wild" geese in several small flocks also used the refuge water areas during the autumn flight, but were easily distinguished from the "refuge" birds by their extreme wariness and disposition to take wing when approached. This number was reduced to 450 by November 21 and in January 1946 only 140 remained, the lowest wintering population in the history of the flock. Sixteen fliers appeared at the refuge headquarters feeding area on March 7, 1946, and their numbers continued to increase until 234 birds were present. By April 10, there were 427 geese using Unit I, all but 25 of which appeared completely at home. Geese then were numerous in Units II and III, but the wild flocks seldom remained longer than three or four days and were most conspicuous by their fear of men.

The inverse relation of the number of young Canada geese produced to the number of pinioned birds is shown in Table 1.

TABLE 1.—CANADA GEESE ON SENEY NATIONAL WILDLIFE REFUGE, MICHIGAN.

Year	*Number of original flock*	*Young produced*
1936	286	15
1938	262	95
1940	221	148
1942	160	200
1944	100	227
1945	45	200

The banding of locally produced geese since 1941 was seriously hampered by wartime conditions; however, 482 goslings were banded of an estimated 2,000 produced on the refuge since 1936. Returns have been received on approximately 10 per cent of these from nine states and the Dominion of Canada. Seney-bred geese have been taken in James Bay, Canada and Warner Valley, Oregon, but heaviest returns have been from states along the Mississippi Flyway, Michigan and Arkansas leading. Nine per cent of the returns were from birds shot in the immediate vicinity of the refuge one or more years following their banding.

CONCLUSIONS

Ten years of study and management of the Canada goose at the Seney Na-

tion Wildlife Refuge yields the following conclusions:

1. Nesting birds cannot be crowded; not more than one nesting pair to each half acre or acre of nesting territory has been found desirable.

2. Seney-bred geese move mainly along the Mississippi Flyway, but are of most importance to local hunters.

3. Birds produced on the refuge return to the area of origin following their southern migration, but further banding is needed to determine the percentage that returns.

TRAPPING WILD TURKEYS IN SOUTH CAROLINA[1]

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Considering the scarcity of published data on trapping the wild turkey (*Meleagris gallopavo*), the following observations may interest wildlife managers in the Southeast. During five years since 1938 the writer has participated in trapping in several areas. On the Bull's Island unit of the Cape Romain National Wildlife Refuge (Charleston Co., South Carolina) the remnants of an introduced "impure" stock were live-trapped and removed; the island later was restocked with a good strain of wild birds from the adjacent Santee River section of the Francis Marion National Forest. Still later, some of their island offspring (Pl. 2, D) were trapped for release elsewhere, and others were captured and released on the island to test trapping techniques.

In August and September, 1943 the writer assisted with the trapping program at the Kentucky Woodlands National Wildlife Refuge. Procedures employed there have been described by Sylvester and Lane (1946).

This article reflects the writer's interpretation of these experiences, with some reference to observations in Kentucky.

These notes are based on the capture of only 70 South Carolina turkeys, but the trapping often has been experimental and selective, and in both deciduous and broad-leaved evergreen forests, where the populations varied from one bird to 15 acres to one per 100 acres. Incorporated here also is the knowledge gained from several hundred hours of observation, from blinds, of turkeys feeding in and around traps.

BAITING

It is first necessary to select as trap sites places through which turkeys travel most commonly. On protected refuge areas, the natural terrain is most important, as are man-made features such as fence lines, truck rails, and clearings. The first Bull's Island trap, built in 1938, was near a truck trail on

[1] Most of the South Carolina work described here was performed by Andrew H. DuPre (refuge manager of Cape Romain), William L. Hills, and the writer, with assistance by Harold L. Blakey, Erwin Driggers, Waring W. Hills, Charles H. Mills, John Eadie, Jack R. Taylor, and Richard Nesbit.

which the birds traveled through a thick forest undergrowth of yaupon (*Ilex vomitoria*) and cabbage palmetto (*Sabal palmetto*). A half-mile away another trap was successful near the wooded edge of a long waterfowl pond, along the shore of which turkeys moved habitually. In the Santee River country one successful trap was situated on a narrow wooded upland ridge bounded by swamp forest and fallow fields. Since the clearing of 60-foot fire lanes on Bull's Island, all traps have been located on the edges of these and of woods roads. Traps should not be located on roads to which the general public has access. At Kentucky Woodlands the best traps were along creek banks, woven-wire fences, and woodland truck trails.

Some turkeys can be attracted to bait during any month of the year. In South Carolina, however, the summer is not suited for trapping because of the nesting season and the heat; nor are late autumn and early winter entirely satisfactory because the abundant acorn mast then available competes with the bait. In southern areas generally free of snow, the two best trapping periods are September–October and January–February, the former being preferable. The presence of snow covering natural foods increases the use of established bait spots and renders trapping easier.

Various grains and seeds have been tried as baits, but the best are wheat, rough rice, and chicken scratchfeed (containing cracked corn, wheat and other seeds). Having selected potential trapping sites, baiting can be started in July and August for early autumn trapping. Only two or three bait spots should be established for each group of turkeys, and it is not desirable to scatter more bait than the flocks can consume at one or two feedings.

When movement to a bait spot assumes a rather regular place in the daily or periodic activities of a flock, construction of a trap can be commenced and other bait spots for this flock eliminated. Once acceptance of bait has been established, two out of three flocks will arrange their daily movements to secure an early meal of grain during the first two or three hours after daylight. After frequent observations of bait spots, one soon can determine when the birds can be usually expected. As many as five different groups of turkeys have fed during one day at a favored bait site, a condition which facilitates trapping.

Squirrels, skunks, opossums, raccoons, rodents, wild hogs, crows, and small birds may become so persistent in taking the food at bait spots and traps that all is gone before the turkeys can reach the site. Judicious use of a rifle on non-refuge areas to remove three or four squirrels or several hogs usually will correct these conditions. Another method is to set steel traps on the site at dusk and remove them the next morning before daybreak, thus using the traps only while the turkeys are on roost. This practice, if not properly carried on, can be dangerous to turkeys. Whole corn and other large seeds are more readily taken by hogs, squirrels and crows, while the smaller chicken scratch is attractive to cardinals and sparrows; but control measures for birds never have been necessary in our experience.

TRAPPING PROCEDURES

The many details that insure success in trapping cannot be described in detail, but some important features of

trap construction in relation to turkey behavior may be mentioned.

All ground traps in "new" trapping areas should be built gradually to allay suspicion by the birds. The sudden appearance of a 20-foot square pen in a favored range would add to the turkeys' natural caution. Once a trap has been established, however, the birds accept it more readily in succeeding seasons. At Bull's Island, turkeys have even fed inside the Pisgah-type deer traps which had been in place for years, finally being accepted by the birds as part of the environment. At Kentucky Woodlands turkeys approached certain wire traps built into or near woven-wires fences more readily than isolated traps; accordingly, pole traps built into rail fences might be more acceptable.

In locating any trap, the natural cover should serve to provide some camouflage for the sides and top, with a few natural clumps of brush breaking, but not hiding, the trap form. Some slender shrubs may be left inside the trap, but the interior and entrance should be fairly open.

Wire ground traps three to five feet high do not catch turkeys so readily as those six feet high or higher: and traps with sides 20 to 30 feet long are better than those 10 or 15 feet square. In the areas studied, the average flock is not large, yet we seldom have been successful in taking an entire flock. On many occasions we have crouched in a blind, tense from the daybreak cold and excitement, while a dozen turkeys would be congregated 50 feet away around the 12-foot entrance, scratching, feeding, and fighting, until two or three would finally move under the overhead netting. In most cases, these birds would then break their feeding routine to chase out others following them into the trap. This trait, possibly akin to the "peck dominance" recognized by poultrymen, hampers trapping, because the hopeful operator delays springing the trap on the chance that "tomorrow" the entire flock will enter; it seldom does. Since crowding at the feeding site apparently causes this intraspecific friction, traps 20 feet square are apparently better than those of smaller size. Some four-year old traps at Bull's Island only 10 feet square are now readily accepted by small groups of turkeys; but future traps would be built to the larger dimensions.

In the gradual construction of a new trap, of either poles or netting, the two sides are placed and invisibly staked at the ground line, then the birds baited in front and between the sides. After the back has been added and baiting has continued for a few more days, portions of the top netting are added, starting from the rear and working forward—but, the top may be added before the back. The top netting must be supported by fine wires to overhead supports or to small upright poles within the trap. One of the greatest difficulties is to induce the turkeys to continue feeding in the trap after the top netting has been placed.

Trap framework should be kept at a minimum, using trees as supports wherever possible. It is best to omit any wooden cross-bracing over the front, under which turkeys must feed, and use a stout wire instead. The material used in wire traps is one- or two-inch poultry netting, the latter being preferable since it is less obtrusive. Wire "weath-

ered" to reduce the shine or painted green is preferable to new wire. For the top fish netting is better than poultry wire, as it results in fewer head injuries to the birds. Painting a fish net may harden it so as to cause as much injury as wire netting, and dyeing the net is a better practice.

Prior to actual trapping the netting should be tested for any weakness, the sides for adequate lacing and staking, and the triggers and release cords for free action.

There are certain aspects of age, sex, and range of turkeys which affect trapping results. Gobblers are more easily baited and trapped than hens in protected areas, but the reverse is true in hunted sections. At Bull's Island, and Kentucky Woodlands (Sylvester and Lane, 1946), the natural population of gobblers is large and relatively undisturbed by hunting, and gobblers were trapped easier than hens; but, in the Santee country, legal and illegal hunting keeps the adult gobbler population low and the few wary gobblers present were seldom seen, occasionally baited, and never trapped during two seasons. Steinhart (1936a), trapped in adjacent Georgetown County, S. C., and found a similar condition, where five months of effort were required to trap two adult gobblers on plantation lands.

If traps are operated in September, poults of the year can be trapped readily. Those up to two months of age are so inexperienced that on occasion we have ridden up on a flock and caught some by hand as they attempted to run through dense roadside vegetation. Adults, under the same conditions, take wing. Every month added to the age of autumn poults increases their wariness at traps. September poults often enter a trap when the parent hen will refuse to do so. Hens with poults have been seen to approach traps, the poults feeding in and the hens remaining outside, only to have adult gobblers arrive, enter the trap and drive all other turkeys from the site.

POLE TRAP

The usual pole trap is 12 to 20 feet square, and three or four feet high. A small pole trap is illustrated by Mosby and Handley (1943, p. 61). Plate 2, B shows a pole trap (photograph by A. H. DuPre) with the trench entrance. This particular trap was modified to use a drop door in connection with the trench. Practically any type of poles can be used; in the Santee country split and weathered pine "light-wood' rails were used in permanent traps. If made of poles two to five inches in diameter, a trap rising three to four feet above the ground will be five to eight poles high, leaving spaces not greater than five inches between them.

In the olden days a pole trap was gradually built up with the top of poles rising to an apex, and turkeys apparently entered them freely. According to Bent (1932), Audubon reported, a century ago, that up to 18 turkeys were caught in a log pen at one time. Coincident with the decrease in turkey population, the sagacity of the birds has increased to preclude such success with pole traps in this region. The usual timidity exhibited by adult birds around a pole trap requires use of a netting top to eliminate trap bulk.

For an entrance, a ditch is dug under the bottom pole; it should not be more than two feet wide or deep at the deep-

est part, and should taper gradually into the middle of the trap (Plate 2, B) and for an equal distance out from the trap front. One or two poles are placed at a time, and at first the turkeys will jump over them to enter the trap; but as the height increases they begin to feed through the trench, and then fly or jump out of the enclosure when finished. A roll of netting on the back of the trap can be progressively unrolled over the top, a little each day. Finally the netting completely covers the top, and turkeys are captured automatically upon their next feeding into the trap. Once captured, they tour the inside walls. To prevent them from falling into the trench and escaping, a two-foot width of the trench immediately adjacent to the pole front is covered with boards or poles and camouflaged with dirt. At the beginning of a new season of activities, it is usually necessary to roll the netting back and remove some of the poles to encourage the turkeys to enter a pole trap.

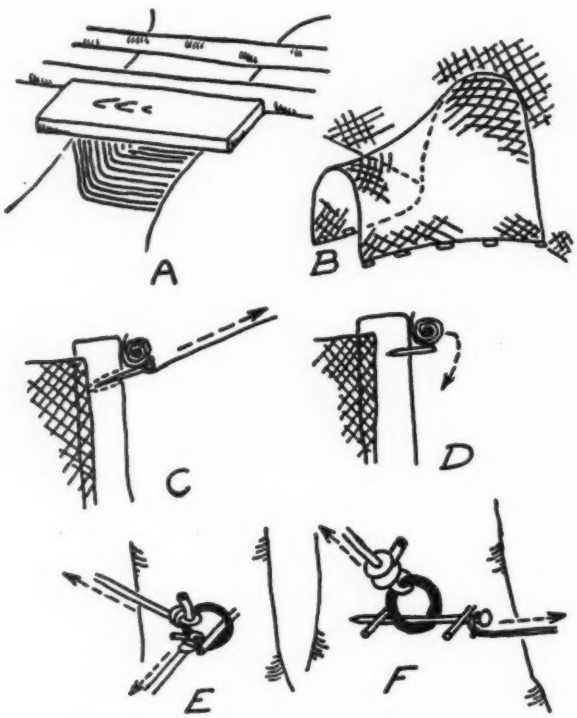
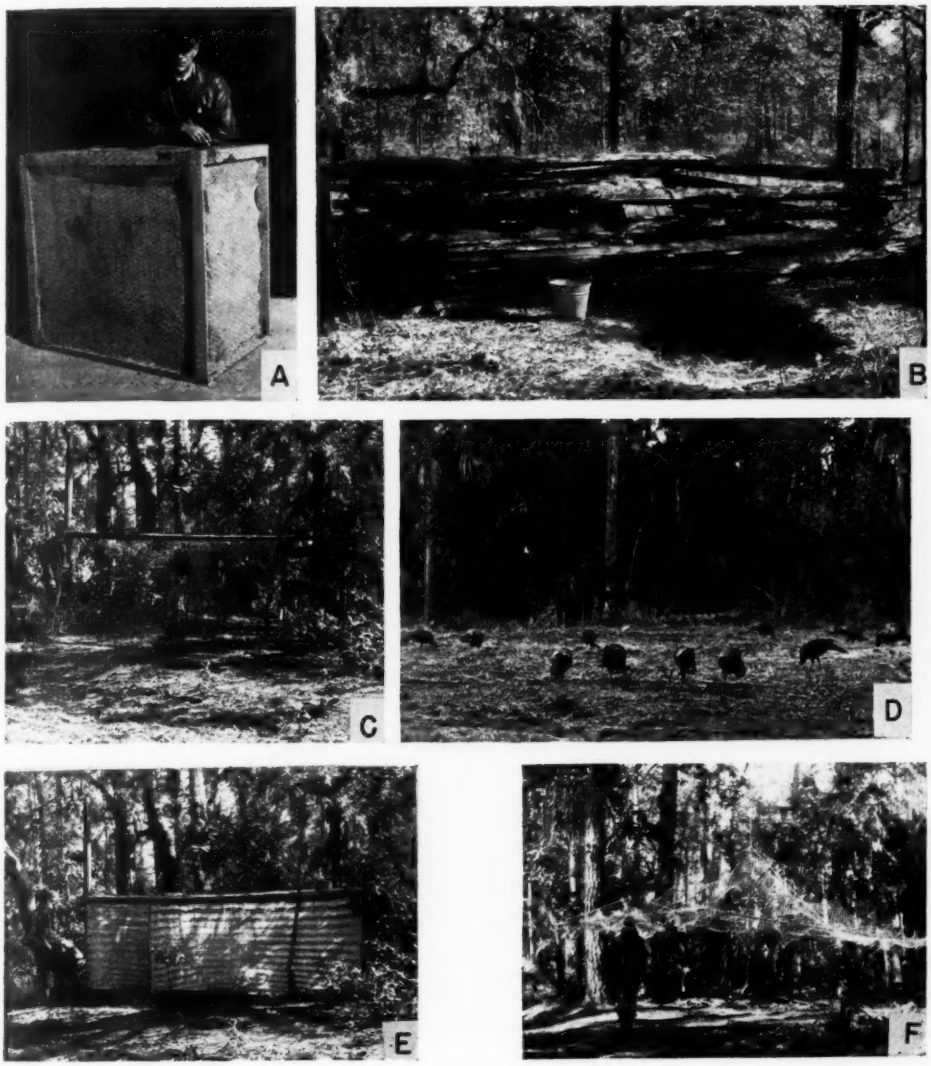


FIG. 1.—Turkey trap mechanisms (not to scale); A. Inner opening of pole trap trench; B. Inner opening of funnel; C. Release end of roll-front trap; D. Fixed end of roll-front trap; E. Modified metal-bar trigger; F. Metal-bar trigger.

In our experience most turkeys exhibited such caution about feeding in



A. Gobbler shipping crate constructed of plywood, cypress, poultry netting, and burlap. *B*. Pole trap of weathered rails, with trench entrance. *C*. Roll-front trap showing curtain in "set" position. *D*. Wild turkeys of Santee River (S. C.) stock, feeding in fire lane at Bull's Island, S. C. *E*. Roll-front trap showing curtain in "sprung" position. *F*. Drop-net trap lowered to six-foot elevation to show detail.

the trench beyond the trap edge that it proved expedient to dispense with the trench, and to cut an opening 30 inches square at the ground level. This type of trap can be operated with a small drop gate, or "rushed" from a blind.

Robert J. Wheeler, Jr., has used pole traps at the Salt Springs Game Sanctuary, Alabama, with greater success than we had. As compared with other traps, the lesser acceptability of pole traps by wild turkeys has not justified the labor of construction required.

FUNNEL-ENTRANCE TRAP

Another automatic trap, with a funnel entrance, is built entirely of poultry netting. This is based on a design by Mr. P. L. Hovey, of Brookgreen Gardens, who used the trap in the Waccamaw River bottoms, Georgetown Co., S. C. It is a square trap, similar to conventional waterfowl traps, of wire netting, 10 to 20 feet square and six feet high, with a top of wire or fish netting, but constructed gradually. When three sides and the top are in place, the front is added; the latter has a ∩-shaped opening about 30 inches square, centered in the bottom edge of netting. A few days may be required before the turkeys will enter the hole to feed within the trap. The funnel then is inserted: it is 24 to 30 inches long, with the outer opening which joins the trap about 30 inches square, and the inner opening 22 to 24 inches high and 12 to 15 inches wide. The funnel is tapered, curved on top and straight sided, with out a wire bottom, and the lower edges staked invisibly to the ground. Thus the funnel is supported only by the wire of which it is built; captured turkeys jumping on it seal themselves in when the funnel collapses.

Once the funnel has been installed, the trap is set and should be examined several times a day. It is good practice to bait the trap, funnel, and ground nearby at dusk on one day, then to visit the site at noon and dusk of the following days. In this way the birds are not disturbed at the time they are most likely to approach the trap, and captured birds are not left all day or night. The most crucial stage in this prolonged method of trapping is the attempt to bait the birds through the funnel. They may decline to enter, feeding outside the trap for a week or more, but judicious reduction of the bait on the outside eventually leads some to enter the trap. Even after a few in one flock are captured, the others will return on succeeding days, if not disturbed while feeding. One funnel trap caught six of nine birds, two on one day and one each on four days. The tendency of this type to catch only a few birds from a flock makes it generally undesirable.

To shorten the trapping period, the funnel can be eliminated and the trap "rushed" from a blind after the turkeys have entered through the hole, the operator springing from a nearby blind and closing the entrance with netting. "Rushing" any type of trap has not yet resulted in the capture of an entire flock, and the birds which escaped have never returned to that trap site during the same season. Furthermore, turkeys just outside the trap, when rushed, never went back inside, but always escaped by flying up and away.

OPEN-FRONT TRAPS

Seeking a trap that would catch

more turkeys, the funnel trap was modified by leaving the entire front open to provide more feeding room for the birds. Several traps of this type can be built, and, being operated from a blind, they permit immediate removal of captured birds. The type used principally in South Carolina has been a "roll-front" trap designed by DuPre. It utilizes a curtain of heavy muslin or white twill, which completely fills the open trap front. The upper edge of the curtain is attached to the top of the trap framework, and the bottom is bound to a length of half-inch pipe. Extending a few inches beyond each side of the trap, the curtain is rolled up tightly and evenly on the pipe (Pl. 2, C). The outside of the rolled curtain is painted green and brown, and can be camouflaged further with a few strands of vines. Having a diameter of two to four inches, this roll is noticeable, and turkeys feeding under the netting before the curtain roll is added often will not continue after it has been placed.

Two nails, one on each front support, hold the rolled curtain (Fig. 1, C–D). One 60-penny nail is the release mechanism, fitting into a hole bored with a slightly larger diameter; this nail is pulled by a cord or wire from the blind. The other support is a 40- or 60-penny nail and stationary, being driven into the post at right angle and the head removed to leave a 2- or 3-inch stub projecting; the curtain roll should just balance on this nail. When the pull-pin (Fig. 1, C) is jerked by the operator the curtain commences unrolling on that end, resulting in the opposite end jumping off the short, stationary pin (Fig. 1, D), and this results in a rapid and fairly even unrolling of the curtain (Pl. 2, E). The largest single curtain successfully operated has been 15 feet wide; and two 10-foot curtains, operated from a central trigger, were used on traps 20 feet wide.

The release cord is dyed sash-cord, telephone wire, or other strong wire. It is threaded through pulleys attached to trees at 8 to 10 feet above the ground. When this is not possible, the cord can be laid on the ground in front of the trap, apparently not being noticed by the turkeys. If so arranged, the pull on the release pin is downward, and the hole in which the pin fits must be bored at a different angle than when the pull is slightly upward from a pulley-suspended cord. To avoid jamming, the angle of repose of the pin must be an extension of the ultimate axis of operation of the release cord (Fig. 1, C).

Upon release of the curtain, the trapped turkeys usually flee to the back of the trap and the operator rushes from the blind at the same instant. One man can operate this trap, but two are better. To prevent the curtain from accidentally unrolling when no one is in attendance a few turns of small wire are made along the roll, and removed before the operator enters the blind for trapping.

The "roll-front" trap is superior to the funnel and pole traps in catching more birds at a time. On many occasions, however, we have been able to trap only a few birds from a flock because the majority refused to feed under the roll of curtain, or willing, were kept out by the boldest of the group.

A trap of this general type was described by Goodrum (1941); it is made of cord netting rather than poultry-wire, and with the roll front of netting

instead of cloth. This Texas trap, of 2-inch mesh no. 16 cord, was 40 by 50 feet and dyed forest-green. It was used in capturing 731 Rio Grande turkeys in brushy country. Harold L. Blakey has used the same type of trap successfully in Texas. The net-traps described by Arrington (1945) were successful in Arizona. Constructed of no. 36 or no. 120 cord, nets of the heavier material were considered better since they were more conspicuous and under the conditions in Arizona it was desired that the turkeys see the netting and not be frightened by flushing prematurely into less visible netting. This is a line of reasoning opposite to that we followed, our practice having been to make the netting as unobtrusive as possible. In general, it would appear that turkeys of the southwestern brush areas are more likely to enter open-front traps than those of the eastern forests.

Two other open-front traps are the "drop-front" and "slide-front." The former was developed in Kentucky by Sylvester and Lane (1946), and has the hinged front as an extension of the top netting. It has not been tried in South Carolina. The "slide-front" trap closes by a panel of netting stretched on a pipe framework, which is raised vertically about 12 feet into the forest-canopy and which slides down two guide wires. Our experience with this trap has been limited; it is more difficult to build than the "roll-front" but may be more acceptable to adult hens with poults than the curtain trap.

DROP-NET TRAP

During the past few years at Bull's Island, some adult gobblers became so accustomed to permanent traps that they entered them for bait with what can be considered as "wild abandon" for a turkey, but the hesitancy of many turkeys, particularly hens, to enter any of the previously described traps has made trapping uncertain, protracted, and costly. With an abundant natural food supply, wild turkeys find the bait within traps only of passing interest.

A trap was needed that, when baited, would be just as acceptable to the birds as a bait spot with no trap. With this in mind, the writer constructed a "drop-net" trap in 1943 at Kentucky Woodlands. The first was a sorry-looking affair, but two days after it had been suspended over a bait spot turkeys fed beneath it. In contrast to the weeks of "coaxing" which may be needed for other traps, this experience was most unusual. During the next two winters, at Bull's Island, improvements were tried.

As now developed, the frame is 15 ×20 feet, of half-inch galvanized pipe with tight elbows and unions to prevent warping, and the net is woven from No. 12 soft-laid twine, with a 4-inch square mesh (8-inch stretched mesh). This size of mesh permits the birds to push their heads through, assisting entanglement, and is believed to be better than a smaller mesh; but the best size remains to be determined.

The netting is larger than the frame and bound to the latter. Eight guys, of ½-inch rope, run from the frame to an apex five feet above the plane of the frame. The netting is painted green and further camouflaged with sprigs of brush and vines, and tied to the guy ropes in places to form a pocketed canopy. The trap is hoisted on a one-inch rope through a single block into the canopy

of a tree until the frame is 12 feet above the ground. A closed vegetative canopy completely blocking off the sky light is a most important requirement. If the pipe framework sags anywhere, the guy ropes are adjusted accordingly. To prevent the net from turning when suspended, several ⅛-inch guide wires are strung perpendicularly from the tree to stakes. These guides run through 2-inch rings fastened to the frame.

If the supporting tree has been selected properly, the net in the set position will blend somewhat with the forest canopy. Where a proper tree limb is not available the single block can be attached to a cable strung between two trees. Plate 2, F shows an uncamouflaged net hoisted to a height of six feet to show detail. Turkeys will not go under the net at this height, but at 12 feet flocks went under it repeatedly, in some instances on the first day of baiting. Sylvester and Lane (1946) state that later drop nets of poultry netting at Kentucky Woodlands were too heavy and obvious, particularly after the winter leaf-fall, and were not attractive to turkeys even when 15 feet above the ground.

The pipe framework of a drop net would injure or kill turkeys (and humans) if it were to fall on them. This chance is minimized by piling a slight line of branches and forest debris on three sides of the ground boundaries of the trap. When the net is released, the framework slides down the guide wires instantly, hitting flat and just inside the lines of trash. The side most used as a turkey approach is left free of brush. As a further aid in keeping turkeys in the middle of the site, only the central portion is baited on the morning of trapping. It is best to wait until all birds are feeding with heads down before releasing the net. Although the drop is instantaneous, gobblers and hens have perceived the dropping net and flown horizontally beyond the trap limits before it covered them.

Two types of release triggers have been used, one being the "metal-bar" trigger described by Ruff (1938). It is made of a ring, two 40-penny nails driven into a tree trunk (the heads removed), and the pull-bar of a 60-penny nail (Fig. 1, F). This is best used when the trigger tree is between the trap and blind. A modified and more reliable trigger (Fig. 1, E) and is made by driving a 60-penny spike into the tree, and removing its head. A 2-inch ring is attached to the block rope, and the release cord runs at right angles to the tree trunk into the adjacaent blind. To prevent the ring end of the rope supporting the net from whipping up to the block upon release, a light line is attached and the other end tied around the tree trunk, allowing plenty of slack to prevent interference with the fall of the trap. When resetting, this light line is pulled down, bringing down the ring and heavy trap rope.

Some birds approach the drop-net with caution, but most of them feed freely under it a few days after erection and baiting. It has not been sprung on a flock containing more than six turkeys, although as many as 13 have been seen feeding beneath the net at one time. This relatively small net would be dangerous to use on large flocks; subsequently we have learned of larger drop-nets used in other regions. Glazener (1944) described a successful drop net used in Texas that was 75 feet square;

it was released simultaneously from four corner posts and a center pole. The Texas Game Department has a blueprint of the trigger mechanism.

The writer concludes that a drop net trap is more efficient than any of the ground traps described. The large nets used in the Southwest have not been tried in South Carolina, but limited experiments with the smaller unit indicate that drop nets are the climax of an evolutionary trend in trap-building. Our earliest trapping costs averaged up to $100 per bird, whereas the latest were as low as $10 per bird.

HANDLING TURKEYS

To remove turkeys from a trap, it is best to enter with a supply of clean burlap bags, preferably one for each turkey. The birds must be caught and bagged rapidly. A tie string should be attached permanently to each bag throat. No more than two adult gobblers are to be placed in one bag. The turkeys then are taken to crates nearby. Deaths occur when the birds are carried long distances in bags; bagging serves only to quiet the birds and to protect them from trap injury. Some operators have collecting chutes attached to the traps and remove turkeys by driving them through such passageways into the crates.

The best type of crate has not been established. Goodrum (1941) and Arrington (1945) claim that turkeys should be crated individually to avoid trampling losses on long trips, and Sylvester and Lane (1946) also favor individual shipment, describing single crates having inside measurements 6 to 12 inches wide, 30 inches long and 30 inches high. Our experience indicates that losses can occur in multiple crating, but such losses appear to have been caused by cramping, exposure, and trampling of small birds by large turkeys. To avoid this, our latest crates permit ample head room, and the age classes and sexes are separated in shipment.

Mosby and Handley (1943), in shipping pen-reared wild turkeys, employed crates 36 inches long, 24 inches wide and only 24 inches high to hold six hens or four gobblers. Some of our earliest crates were 48×30×30 inches. Successive changes have resulted in a lighter crate with more headroom, that for a gobbler (Pl. 2, A) being 44 inches long, 28 inches wide and 41 inches high. The construction consists of ½-inch plywood bottom, corner uprights, and top framework of 2½×¾-inch dressed cypress, with all corners reinforced by 4×4-inch angle braces. To elevate the plywood floor from the ground a narrow strip of ¾-inch cypress is attached around the bottom edge. The inside of the crate is lined with a single thickness of clean burlap, stretched tightly between the corner posts, and the outside and the top are covered with poultry netting, one corner being left unstapled for putting the turkeys through the top. A fairly taut top buffer of burlap is sewn to the burlap sides six inches below the poultry netting top, the resulting distance between floor and head buffer being approximately 35 inches, a height which permits gobblers to stretch upright and avoid leg cramping. The burlap lining provides air and light without vision, and the head buffer prevents scalping. The inside height of crates for hens and poults can be eight to ten inches less than for gobblers.

This crate will hold three adult gobblers, four hens, or six well-grown poults with no crowding. Its use has been limited, but it seems to be giving better service than some of other dimensions. The empty crate weighs 50 pounds and three crates will fit into the body of a half-ton pickup truck, with three more lashed above them. Regardless of the autumn or winter temperature, it is best to stop direct drafts on the crates with a tarpaulin, and to examine the birds every 50 miles during transit for evidence of heating or chilling. Manipulation of the tarpaulin will prevent losses from these conditions. For transfer, personally operated trucks are superior to common carriers. Steinhart (1936b) shipped pen-reared wild turkeys successfully to England in lined and slatted crates.

The birds should be transported as soon as trapped, but on occasion they have been held in crates with feed and water for a week, with no obvious ill effects other than feather loss.

RELEASING TURKEYS

If the birds have not been banded, they must be pulled from the crates for this purpose, which usually results in additional feather loss. It is better to band them prior to the original crating. Then, at the time of release, a corner of the top wire and buffer of the crate can be pulled aside, and, if the operator stands out of view, the birds will fly out and away. It is desirable to choose a semi-open wooded area for the release so the birds will not collide with trees, brush, or fences.

Some operators have confined turkeys to holding pens in the new habitat for a short period, but it is doubtful whether this is desirable, since immediate access to water, food, and safe roosting trees will minimize straying. Fairly large releases of both sexes at one spot helps to prevent wandering from the area during the mating season.

BLINDS

Some of the traps here described were operated from a blind. Considering the sagacity of the wild turkey, it is mild to say that the operator must remain quiet and relatively motionless. The blinds were 25 to 150 feet from the traps, and placed to take advantage of natural clumps of cover. Brush placed around the framework of a blind should blend with the surroundings. At Bull's Island, broad fans of the evergreen cabbage palmetto (*Sabal palmetto*) made good cover, but any deciduous brush can be employed.

To construct a blind, a wooden framework is covered with burlap, making movements within less visible from the outside. The burlap is camouflaged with brush nailed to the framework and piled around the structure. A blind with ample room for one or two occupants should be 4 feet square and 4½ feet high, with a bench on the inside.

Turkey trapping employing blind-operated traps in regions where mosquitoes are abundant can be uncomfortable, sometimes impossible. A screened blind build by DuPre for the Santee country has proved valuable. In the temperature zone of Charleston, S. C., the screened blind is desirable for observing or trapping between March 1 and October 15. The framework is ¾×1½-inch lumber, braced on all corners, and is covered with screen wire; it is 58 inches high, 36 inches across the front and 45

inches deep, with the front hinged as a door. When painted green and camouflaged with brush it is invisible to wildlife, and if the interior is properly darkened the operator cannot be seen from the outside.

BANDING

There is little information on the leg diameter and proper size of band to use on actually wild turkeys. Game-farm "wild" turkeys have stouter legs than the purer wild stock. At Bull's Island, the band used is the "split-ring" type issued to bird-banders by the U. S. Fish and Wildlife Service. Upon closure, it has a continuous smooth surface inside and out, important for a ground-dwelling bird, and far better than plastic or metal poultry bands with projecting flaps or of "wrap around" construction.

TABLE 1.—LEG, SPUR AND BEARD MEASUREMENTS OF SOUTH CAROLINA WILD TURKEYS, JANUARY, 1945.
(All measurements in millimeters)

	Relative age and sex			
	Males		*Females*	
	1st yr.	*Adult*	*1st yr.*	*Adult*
Number of birds (15)	1	8	2	4
Leg diameter, extremes	18	19–21	14–15	16–17
average	18	19.6	14.5	16.2
Spur length, extremes	5	21–34	—	—
average	5	26.5	—	—
Beard length, extremes	75	227–263	—	—
average	75	248	—	—

On adult gobblers the metal band is placed between the spur and hind toe. Of 15 Bull's Island turkeys measured in January 1945, the maximum leg diameter at this point was from 14 to 21 mm., depending on age and sex (Table 1). Nearest to this size range is the No. 8 band, having an inside diameter of 22 mm. (14/16 inch). The largest gobbler leg measured 21 mm., but of several old heavy gobblers shot near the Santee River during the same winter, one had a leg diameter of 22 mm. Thus, the largest shank diameter of a gobbler would probably fill a No. 8 band. Several years ago when we did the first experimental banding of gobblers, we cut a few bands to an inside diameter of 19 mm., but this is no longer done. The 22 mm. band will seem loose on a young gobbler of the year, but it is suitable so long as it will not slip down over the hind toe or above the "knee" joint.

For hens the full size No. 8 band can be used, but is a bit loose on the 17 mm. leg of an adult. It is better to cut off about 15 mm. (9/16 inch) of the *circumference* to yield a hen band with a new *diameter* of 18 mm. (11/16 inch). This presumably will care for complete leg growth of a hen. Autumn birds of the year can be banded with the proper size after sexing, but summer poults cannot be leg-banded with the sizes described, since the bands slip off. Mosby and Handley (1943) indicate that wing-banding is the best method for marking turkeys up to one month of age and leg-banding thereafter. Our experience would indicate that leg bands are not satisfactory until the birds are three months of age.

In modifying bands it is best to use a hacksaw, smoothing the cut edges with emory cloth. Many observations from blinds have shown that bands so cut were not bothersome to wild turkeys scratching vigorously for feed. Three birds trapped two to four years after original banding had no evidence of callus or other irritation from bands so applied.

SUMMARY

Experience since 1938 in live-trapping 70 wild turkeys in coastal South Carolina revealed that preliminary and experimental trapping cost as much as $100 per bird but that later operations on established trapping sites cost as low as $10 per turkey. The ease of trapping depended on many factors, particularly the season, the age and sex of birds, hunting pressure, and the location and types of traps. September and October trapping was best, and refuge areas offered better possibilities than hunted sections.

Two automatic traps, the pole and the wire funnel types, were used, but were inferior to traps manipulated from blinds. The observer-operated trap most used was of a "roll-front" type employing a curtain to close the entrance. Later experimental use of a "drop-net" trap revealed it to be more readily accepted by turkeys than other types. Further experiments under southeastern conditions are needed, but some form of "drop-net" may be the most efficient turkey trap.

Shipping crates of several types were used, but a light-weight plywood, wire, and burlap crate was developed which has given satisfactory, though limited, service in multiple shipment of turkeys.

For banding wild turkeys the No. 8 split-ring band of the U. S. Fish and Wildlife Service proved satisfactory for gobblers, but must be reduced slightly in diameter for hens.

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CONTENTS OF CROPS, GIZZARDS, AND DROPPINGS OF BOBWHITE QUAIL FORCE-FED KNOWN KINDS AND QUANTITIES OF SEEDS

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The merits and shortcomings of various methods used to obtain information on the food habits of wildlife have been discussed in many published papers during the past 50 years. This is especially true for gallinaceous birds where the contents of crops, gizzards and droppings have been studied, and where the volume, weight, frequency of occurrence, and number of units of each kind of item have been used as criteria of appraisal. The present experiment was planned to test and compare the assumed differences in a few of these alternative methods.

Methods

Twenty-four mature, bobwhite quail (*Colinus virginianus virginianus*), artificially propagated and reared, were used, 12 males and 12 females. Each was housed in an individual cage, 9×9×12 inches. Surplus of water and grit was provided at all times, and suitable containers were placed under each cage to collect droppings from the individual birds. The weights of the birds were taken at the beginning of the experiment and just before they were killed at the close of the feeding phase.

In determining the seeds to be used in the diets, consideration was given first to those recognized as quail foods, and second to those having various degrees of resistance to digestion and assimilation. Having regard for these factors, 240 similar or practically identical diets were prepared using the seeds listed in Table 1.

To maintain movement of the food through the digestive tract, care was taken to ensure that the crop did not become impacted because of the swelling of dry food. This necessitated three feedings of the proportions shown in Table 1 each day instead of one large feeding. The narrow end of a glass thistle tube was lubricated and inserted

Table 1.—Composition of Diet.

Kind of seed	Number	Volume		Weight	
		Cc.	Percentage of diet	Grams	Percentage diet
Pinus taeda	10	0.38	*13.2*	0.25	*11.8*
Setaria italica	100	0.28	*9.8*	0.21	*9.8*
Triticum aestivum	10	0.39	*13.4*	0.28	*13.0*
Zea mays	2	0.34	*11.7*	0.26	*12.5*
Cassia chamaecrista	50	0.52	*17.8*	0.40	*18.8*
Lespedeza stipulacea	100	0.33	*11.3*	0.21	*9.8*
Robinia pseudo-acacia	25	0.66	*22.8*	0.52	*24.3*
Totals	297	2.90	*100.0*	2.14	*100.0*

through the bird's mouth into the crop, then one unit of diet was placed in the upper bowl and directed into the crop; any seeds adhering to the sides of the tube were cleared with a plunger.

After fasting for 36 hours, force feeding commenced at 12:00 noon, and the second feeding was given at 5:00 P.M. For the next two days, feeding occurred at 7:00 A.M., noon, and 5:00 P.M. On the fourth day, two feedings were given; one at 7:00 P.M. and the other at noon: Forced feeding then stopped, each bird having received 10 separate feedings. Droppings were collected from each individual bird.

After the final feeding, the birds were sacrificed; the crops and gizzards were removed, appropriately tagged, and later analyzed according to standard food-habits procedure (Cottam, 1936; U. S. Fish and Wildlife Service, 1942). Results of the analyses were expressed by weight and also by volume and numbers of seeds, except that for the droppings quantitative determinations were based on estimated percentage of volume.

Of the 24 birds used, 20 completed the feeding trials, and all findings reported are based on the crops, gizzards and droppings from the 20 birds. Of the four not included, three were eliminated because of crop impaction and one because of accident.

RESULTS

The average weight of the birds was 136.4 grams at the time of first feeding, and 130.0 grams at the end of the experiment, a loss of 6.4 grams. The standard error of the difference was 1.004 grams, and the difference is significant above the 1 per cent level of probability.

TABLE 2.—ANALYSIS OF CROPS, GIZZARDS, AND DROPPINGS WITH REGARD TO PROPORTION OF PLANT MATERIAL AND GRIT.

	Crops		Gizzards		Droppings
	Volume	Weight	Volume	Weight	Estimated volume
Plant matter (per cent)	*98.2*	*97.8*	*92.3*	*81.7*	*94.0*
Sand and gravel	1.8	2.2	7.7	18.3	6.0

The contents of the crops, gizzards and droppings are shown in the analysis given in Table 2. It is seen that the gravel, with its high specific gravity, is emphasized when weight is the base. No control over gravel was made and the data relating to gravel are given because they may have value in appraising the general conditions of the experiment.

Figures 1 and 2 show in per cent, by volume and weight respectively, a comparison between foods fed and foods found in crops, gizzards and droppings of the birds in the experiment. By volume, the per cent difference between that fed and that found, ranged from a loss of 4.5 to a gain of 5.1 for crops; from a loss of 16.2 to a gain of 55.8 for gizzards; and from a loss of 11.8 to a gain of 41.0 for droppings. By weight, the percentage difference between that fed and that found ranged from a loss of 5.1 to a gain of 5.7 for crops and from a loss of 17.8 to a gain of 59.4 for gizzards. Dropping estimates cannot be compared with weight percentages because

they are based on volumetric estimates.

Table 3 shows the total range (gain and loss) of differences in per cent by volume and by weight between the amount of food fed and the amount found in the crops, gizzards and droppings, except that weight differences of droppings are omitted for the reason given above. The total and average discrepancies are given for each category. It is observed that crops show least variance with the percentages of food fed, and that gizzards and droppings were approximately 5 and 4 times more variant, respectively. The range of differences for crops by volume and weight were 0.0–5.1 per cent and 0.0–5.7 per cent, respectively, while the range of differences for gizzards by volume and weight were 1.2–55.8 per cent and 1.4–59.4 per cent, respectively. The range of differences for droppings was 1.8–41.0 per cent.

TABLE 3.—TOTAL RANGE OF DIFFERENCES (GAIN AND LOSS) BETWEEN SEEDS FED AND RECOVERED FROM CROPS, GIZZARDS AND DROPPINGS.

Kind of seed	Total difference in per cent in				
	Crops		Gizzards		Droppings
	Volume	Weight	Volume	Weight	Volume
Pinus	*2.3*	*1.3*	*55.8*	*59.4*	*3.8*
Setaria	*5.1*	*5.7*	*6.4*	*6.9*	*1.8*
Triticum	*4.5*	*3.1*	*8.4*	*9.8*	*2.4*
Zea	*0.7*	*1.3*	*9.5*	*10.3*	*10.7*
Cassia	*2.5*	*0.3*	*8.1*	*8.6*	*11.8*
Lespedeza	*3.0*	*2.2*	*8.4*	*7.4*	*8.3*
Robinia	*4.3*	*5.1*	*16.2*	*17.8*	*9.8*
Undetermined	*0.0*	*0.0*	*1.2*	*1.4*	*41.0*
Total discrepancy	*22.2*	*19.0*	*114.0*	*121.6*	*89.6*
Average discrepancy	*3.2*	*2.7*	*14.2*	*15.2*	*12.8*

Table 4 gives a comparison between the results by the volumetric method and the weight method. Differences between these two methods are tabulated for the original feeds, crop analyses and gizzard analyses. The average difference per item was 0.94 per cent for that fed; 0.92 per cent for crops and 0.72 per cent for gizzards. The differences in results can be attributed largely to vagaries of measurement and to sample size.

DISCUSSION

At the end of the experiment the birds appeared to be in good health, but their weights before and after feeding indicate that the research technique caused a decline in their general condition. We believe that this decline could be expected. An abrupt change in their place of abode and their diet, together with the period of starvation, would lead one to expect a change in metabolism and a resultant loss in weight. The extent to which these factors affected the results of this experiment cannot be appraised at this time. In the diet, recognized quail foods were used, but no attempt was made to establish a balanced diet with regard to quantity and quality of food. Instead, diets were prepared to facilitate comparisons between relatively soft and hard foods.

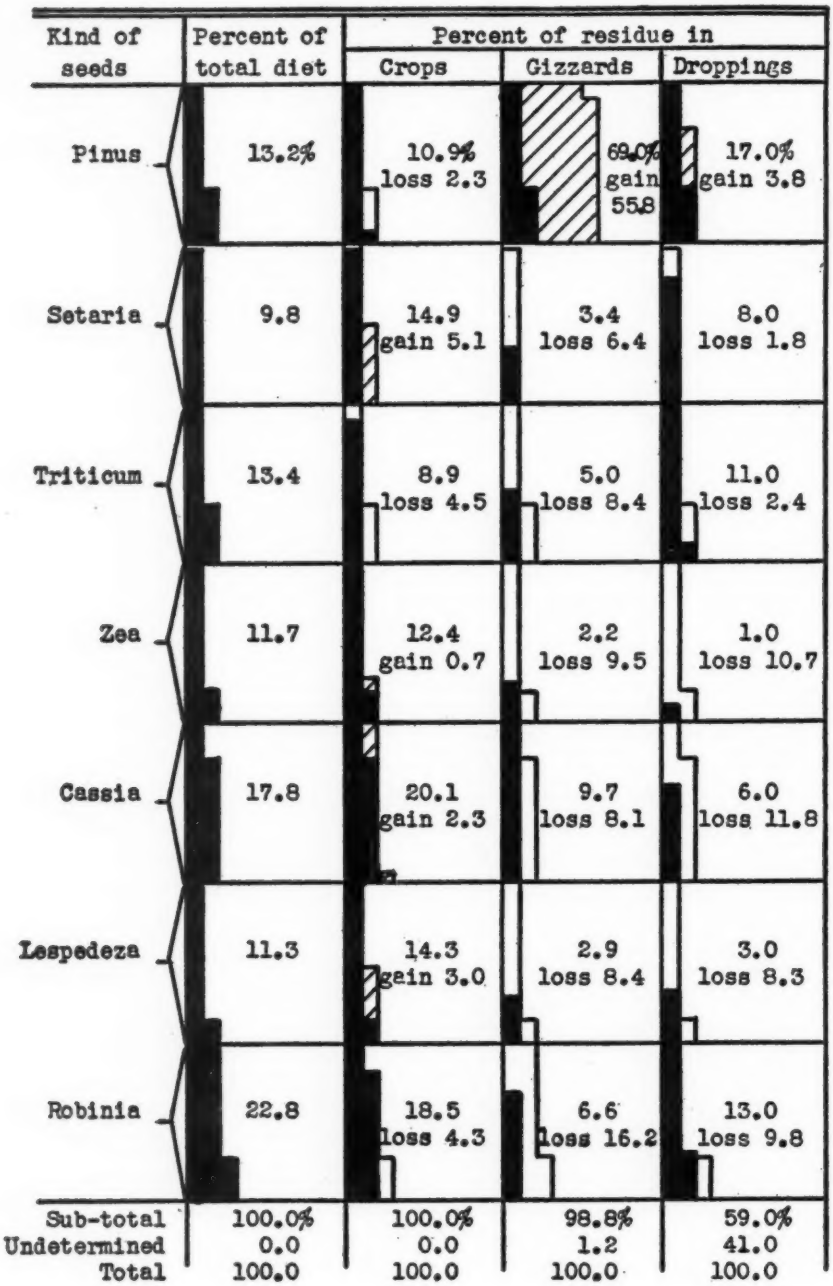

FIG. 1.—Volumetric percentages of seeds fed and recovered from crops, gizzards, and droppings of 20 bobwhites.

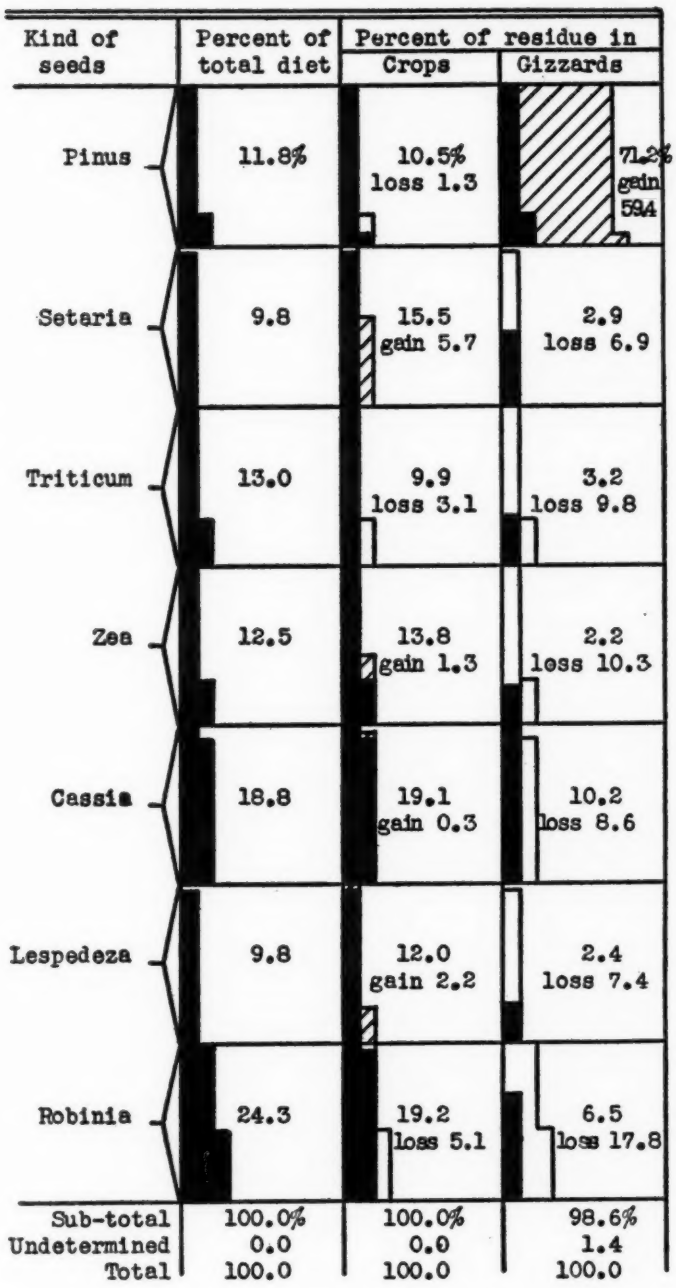

FIG. 2.—Weight percentages of seeds fed and recovered from crops and gizzards of 20 bobwhites.

Additional experiments would be needed to clarify other points. However, they should be kept in mind when interpreting the data from the present study.

Daily diets averaged by volume 8.7 cc. and by weight 6.4 grams. Stoddard (1931) states an average of 12 grams is

TABLE 4. DIFFERENCES IN PER CENT BETWEEN RESULTS OF THE TWO CRITERIA, VOLUME AND WEIGHT, AS EXPRESSED IN PERCENTAGES OF TOTAL QUANTITY.

Kind of seed	Prepared diet	Crop contents	Gizzard contents
Pinus	1.4	0.4	2.2
Setaria	0.0	0.6	0.5
Triticum	0.4	1.0	1.8
Zea	0.8	1.4	0.0
Cassia	1.0	1.0	0.5
Lespedeza	1.5	2.3	0.5
Robinia	1.5	0.7	0.1
Undetermined	0.0	0.0	0.2
Total discrepancy	6.60	7.40	5.80
Average discrepancy	0.94	0.92	0.72

necessary for cocks and hens. This may account partly for the loss in weight reported here. Perhaps feeding should have been more often, but care would have to be exercised to prevent impaction in the crop. If a longer feeding period were used, sufficient time could be allowed to clear the digestive tract of items eaten before the birds were force fed. This would eliminate the necessity for a period of starvation preceding the force-feeding. Even though the feeding methods were artificial, the quail passed the food through their gastro-intestinal tracts and affected a segregation of the food. Thus, it was possible to make desired comparisons.

So far as the data from this study are concerned, volume and weight method are in close agreement. Here, under ideal conditions, the discrepancy between the two methods for the seed-mixture fed, for crop contents, and for gizzard contents averaged less than 1 per cent per food item. In general food habits studies, it is believed that experimental error would exceed these differences considerably; hence, at present

TABLE 5.—PER CENT COMPARISONS OF WEIGHTS OF FEEDSTUFFS.

Feedstuff	Contents of		Difference
	Crop	Gizzard	
Pinus	10.5	71.2	60.7 gain
Setaria	15.5	2.9	12.6 loss
Triticum	9.9	3.2	6.7 loss
Zea	13.8	2.2	11.6 loss
Cassia	19.1	10.2	8.9 loss
Lespedeza	12.0	2.4	9.6 loss
Robinia	19.2	6.5	12.7 loss

such small differences would not be significant.

Specific gravity would be the determinative factor in causing disparity between the weight and volume methods. For management of wildlife, per cent by volume may give sufficiently accurate data. In some aspects of management, for example nutrition, the basis for all comparisons between bird and feedstuff is weight. Measurements of the crop and gizzard contents based on weight would show slightly less variation than those determined by volume. A rough measure of volume can be determined more quickly than the weight. Each system has advantages, and the information required would indicate which method was preferable.

In appraising the imposed food habits of these bobwhite quail, using crops as a basis, the average deviation per feedstuff was 3.2 per cent by volume and 2.7 per cent by weight. Comparable figures for the gizzards are 16.2 per cent and

16.9 per cent. Average deviation for droppings was 12.8 per cent by volume. For this experiment, crops give the best basis for determining the imposed food habits of the quail, and droppings may be regarded as equal in value to gizzards. Combining the crop and stomach data would tend to reduce the effectiveness of the crop data.

There is a possibility that the difference between the crop-contents and gizzard-contents, on either a weight or volumetric basis, might be used in field studies as an index of the total digestible nutrients in any item of the diet. This is illustrated by the following tabulation of the data obtained by weight (Table 5).

Pinus, which is represented by an accumulation in the gizzard, was apparently harder to digest than the other feedstuffs, and, therefore, probably has lower total food value for quail. Inasmuch as it contains over 56 per cent of crude fiber (King and McClure, 1944), this deduction seems plausible. But, on the other hand, *Triticum*, which has less crude fiber than *Robinia* (2.4 per cent in comparison with 15.5–17 per cent), showed less loss in the gizzard than did the latter. Therefore, digestibility trials should be conducted in conjunction with measurements on the contents of crop and gizzard, to determine the accuracy of the latter for appraisal of nutritive value of feedstuffs.

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EARLY INVOLUTIONARY CHANGES IN THE POST-OVULATORY FOLLICLES OF THE RING-NECKED PHEASANT[1]

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As a part of a program designed to study reproductive processes in the pheasant (*Phasianus colchicus torquatus*) as related to population fluctuations in wild pheasants, it became im-

[1] This work was supported in part by a grant in aid from the Wisconsin Alumni Research Foundation.

The authors acknowledge the cooperation of the Wisconsin Conservation Department which furnished pheasants and pens for these experiments. Elton E. Bussewitz helped collect the initial data used in this study. His work was halted during May, 1943, when the Army called him to service, and his brief career in wildlife studies was ended in Normandy, July 25, 1944, where he was killed in action.

portant to determine the number of eggs ovulated during the breeding season. It is difficult to obtain reliable information of this type from nesting studies. However, anatomical changes which take place in the ovaries after ovulation provide a basis for obtaining data from them which would be of value in ascertaining ovulation rate. The wall of the follicle immediately after ovulation is a large structure in the pheasant but rapidly undergoes involution in the early stages as will be shown in this paper. The remains of the wall of the post-ovulatory follicle persists for a long time after ovulation as has been demonstrated in the common fowl by Pearl and Schoppe (1921). In a subsequent paper it will be shown that the remains of the post-ovulatory follicle can be used to determine whether ovulation occurred at a time 4 to 5 months following the breeding season.

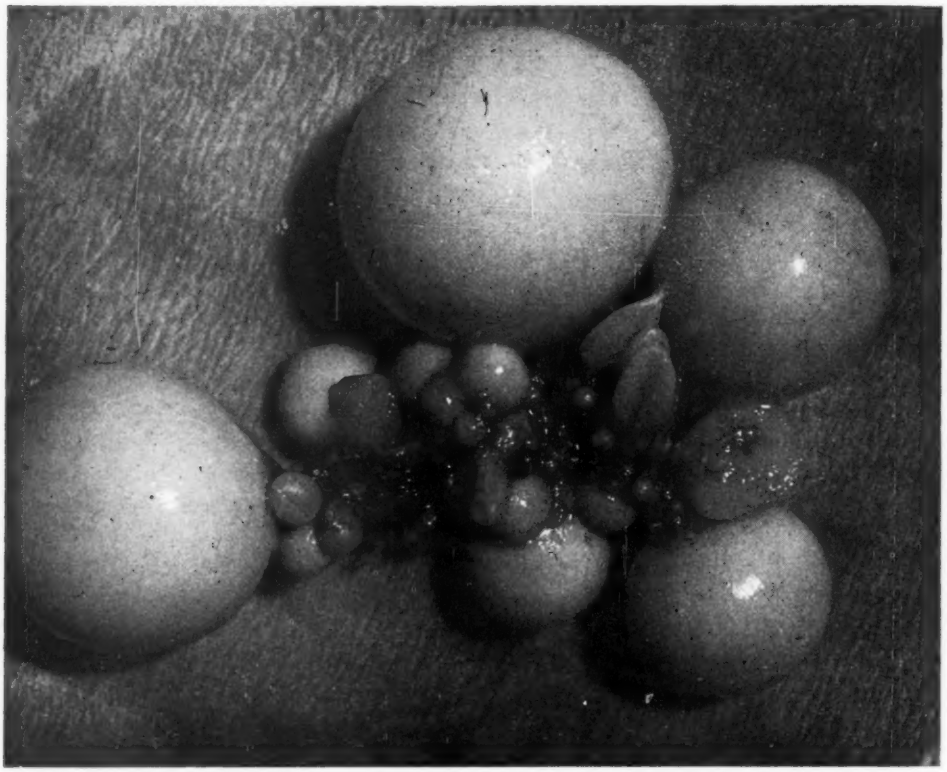
MATERIALS AND METHODS

Ovaries obtained from pheasants killed at varying intervals after having laid known numbers of eggs were studied to determine the rate of involution of the ruptured (ovulated) follicle during the time required by a pheasant to lay an average-sized clutch.

Twenty pairs of 11-month-old ring-necked pheasants, which had been hatched in late May and early June of 1942, were used in experiments conducted during 1943. In 1944 the experiments were repeated using 30 pairs of birds hatched in late May and early June of 1943. Each pair was confined in a pen of the type used for breeding purposes by the State Experimental Game and Fur Farm, having a length and width of 16 ft. and a height of 7 ft. The only form of cover in the pens was a sparse growth of winter rye, some dead annual weeds and a 3 ft. square wooden shelter piece about 14 inches above the ground in one corner. Pens of this size enabled an observer to find all, or nearly all, of the eggs laid. Some birds ate eggs but enough was usually left of the shell to provide evidence that an egg had been laid. To prevent the breaking of eggs, beaks of the egg-eating birds were pared, which operation did not interfere with feeding. The pens were examined at 9:00 A.M. and 2:00 P.M. daily; the number of eggs laid was recorded, and the eggs removed.

The total number of eggs found in the pens was compared with the number of ruptured follicles observed in the ovaries. Nesting studies have disclosed that an average clutch consists of 10 to 12 eggs, but that some eggs are dropped at random before laying begins in the nest. Therefore, for the purpose of this study, it was arbitrarily decided to allow 2 eggs for dropping and 12 or 14 for the size of the clutch. The hen would then produce about 14 eggs during the course of these observations. In order to show the progressive changes taking place in the ovary during the laying of 14 to 16 eggs, 20 hens were killed in 1943 and 30 in 1944.

Hens were killed by chloroform, or by severing the neck vessels, after they had laid the last of a designated number of eggs. In 1943 all birds were carefully skinned, and after an incision had been made underneath the sternum of each bird, it was immersed in 10 per cent formaldehyde. It was found, however, that fixation of the ovaries while in the body cavity resulted in abnormal shaping of the ruptured follicles, thus com-



Ovary of a pheasant removed during the laying season. Six recently ovulated follicles as flat ovoid structures. Many other ovulated follicles which had been involuting for a longer period of time are not visible in the photograph.

plicating the study. In 1944 a more natural condition of the ovary was obtained by first removing it from the cavity and then preserving it in a solution consisting of 10 parts formaldehyde, 10 parts of glacial acetic acid, 30 parts 95 per cent alcohol, and 50 parts water.

Ovaries obtained in 1943 and 1944 were removed from the preserving solution at varying intervals after they had been collected, for the purpose of weighing and counting the ruptured follicles. Unruptured follicles were removed to make it easier to handle the ovaries and to find the smaller of the ruptured follicles. In removing the ruptured follicles for weighing, care was taken to cut the pedicle of the follicle at its smallest diameter.

For purposes of illustration Plate 3 shows the appearance of an ovary removed during the breeding season and after it had been fixed in preserving fluid.

Recently ruptured follicles can be recognized easily as they are relatively large, flat somewhat wrinkled structures. The opening in the ruptured follicle from which the ovum was extruded is opposite the pedicle. The edges of this opening are smooth and if not seen at first can be easily found by exploring that area with a pair of forceps. The fixing fluid which was used caused the follicles to have a grayish or whitish cast, and the blood vessels in the walls of the largest of the ruptured follicles appeared as thread-like structures. As involution proceeds the recognition of ruptured follicles, particularly the very smallest, becomes more difficult. The ruptured follicle becomes smaller as involution proceeds and is molded to a considerable extent by the surrounding follicles. However, when ruptured follicles are approximately 6 to 8 days old a yellow pigment begins to appear in their walls; as involution continues this pigment becomes more concentrated and in the final stages the ruptured follicles consist of small brownish orange structures. Histological examination makes it seem probable that this pigment is hemosiderin, and that involution is characterized by the same changes that Davis (1942a) has described for certain other species of birds. A criterion which is a definite aid in recognizing the small pigmented structures as the remains of ruptured follicles, is the persistence of the ovulation opening. Even follicles which are not much larger than 1 mm. in diameter retain an opening that can often be probed with the tip of a fine pair of forceps. A count of the ovulated follicles in each ovary, based on the criteria just described, was made before consulting the egg record.

After all the large ovulated follicles had been removed from the ovaries they were then taken individually from the fixing solution, the excess fluid removed by pressing them on absorbent paper, and then quickly weighed to the nearest milligram on a torsion balance. Then the number of ruptured follicles in each ovary was compared with the number of eggs which had been laid by the corresponding bird. For the purpose of determining readily whether the number of ruptured follicles found was greater or less than the number of eggs laid, the number of ovulated follicles was divided by the number of eggs found. If this "ovulated follicle factor" is greater than 100, it indicates that

TABLE 1.—WEIGHTS OF RUPTURED FOLLICLES DURING 15-DAY EGG-LAYING PERIOD.

Year[1]	Days after ovulation[2]																No. of eggs found[3]	No. of follicles found[4]	Ovulation factor[5]
	*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
	Weight follicles in mgm.																		
1943 A	282	177	104	77	61	32	16	8	7	4	3	5	5	4	4	3	75	75	100
	8	8	5	5	6	5	6	5	6	6	5	2	2	2	1	1	8	8	8
	190–350	122–277	76–185	25–178	21–90	17–83	8–38	3–12	2–12	2–8	1–5	5	1–4	4	4	3	4–14	4–14	82–150
1944 A	305	177	95	37	19	10	8	5	6	4	2	2	2	—	2	—	64	66	103
	7	7	7	6	4	6	5	2	2	2	2	3	1	—	1	—	7	7	7
	251–388	130–288	62–140	14–71	14–28	6–15	4–14	4–5	2–10	3–4	2	1–4	2	—	2	—	4–16	5–17	100–125
1943 M	264	169	82	31	16	26	10	3	4	4	2	0.5	0.5	0.5	—	—	44	42	93
	5	5	5	2	2	4	3	2	3	2	3	2	2	2	—	—	5	5	5
	194–349	125–234	49–148	24–37	12–20	11–60	7–16	3	3–7	2–5	1–3	0.5	0.5	0.5	—	—	3–13	3–13	83–100
1944 M	265	154	84	52	24	11	7	6	3	2	2	2	1	—	—	—	64	64	100
	10	10	8	5	5	5	4	3	2	2	2	1	1	—	—	—	10	10	10
	228–309	122–191	27–123	16–70	11–39	8–15	3–11	1–9	1–4	1–2	1–3	2	1	—	—	—	2–16	2–16	91–109
1943 V	199	121	65	34	15	13	6	8	6	4	—	5	—	6	5	—	58	60	103
	7	7	7	7	6	5	4	3	1	2	—	2	—	1	1	—	7	7	7
	153–274	99–146	35–94	15–71	8–28	10–16	5–8	4–13	6	3–4	—	2–10	—	6	5	—	5–13	5–12	75–143
1944 V	215	115	55	25	15	10	6	3	1	2	1	—	—	—	—	—	81	81	100
	13	13	9	5	7	6	4	3	3	1	1	—	—	—	—	—	13	13	13
	99–310	71–163	26–99	10–38	5–29	4–19	4–8	2–5	1–2	2	1	—	—	—	—	—	2–16	2–16	100
1943 Av. (A+M+V)	248	155	81	46	35	23	12	17	5	4	3	4	3	3	5	3	177	177	100
	20	20	17	14	14	14	13	10	10	10	8	6	4	5	2	1	20	20	20
	199–282	121–177	65–104	31–77	15–61	13–32	6–16	3–8	4–7	4	2–3	0.5–5	0.5–5	0.5–4	4–5	3	3–14	3–14	75–150
1944 Av. (A+M+V)	253	141	73	38	19	10	7	4	3	2	2	2	—	2	2	—	213	215	101
	30	30	24	16	16	17	13	8	7	5	5	4	—	2	1	—	30	30	30
	215–305	155–177	55–95	25–52	15–19	10–11	6–7	3–6	1–6	2–4	1–2	2	1–2	—	2	—	2–16	2–16	91–125

* Follicles in this column were assumed to be the ones from which the eggs found in the reproductive tract were ovulated.

[1] A indicates those birds in which there was an egg found in the anterior end of the oviduct, M those in which an egg was found in the middle part, and V those in which an egg was found in the vagina.

[2] The first figure in each column is the average weight of the post-ovulatory follicles, the second figure is the number weighed, and the third figure is the range in weights used in computing the average.

[3] The first figure in this column is the total number of eggs found, the second is the number of birds laying eggs, and the third is the range in the number of eggs laid.

[4] The first figure in this column is the total number of post-ovulatory follicles, the second is the number of birds in which the follicles were counted, and the third is the range in the number of post-ovulatory follicles.

[5] The ovulation factor is the figure obtained by dividing the number of follicles found by the number of eggs found. The first figure is the average factor, the second is the number of birds, and the third is the range in the individual factors. Follicles weighing less than 0.5 mgm. are not recorded under "Days after ovulation," but are included in "No. of follicles found."

more follicles were counted as having ovulated than eggs found; if the factor is less than 100 it means that fewer ovulated follicles were counted as having ovulated than eggs found.

When all the follicles from a single ovary had been counted and weighed the weights were arranged from the heaviest to the lightest. The lightest ruptured follicle was assigned to the day on which the first egg was found and the heaviest to the day on which the last egg was laid, or to a time less than 1 day if an egg was found in the anterior, middle or vaginal part of the reproductive tract. This arrangement of the data is based on the assumption that the smallest remains of an ovulated follicle found in a particular ovary was that of the follicle from which the first egg had been ovulated. It is also assumed that the involution rate of different ovulated follicles is the same, but it is recognized that the general condition of the bird, the stage of the reproductive cycle, the number of eggs ovulated, etc., might affect the rate of follicle involution.

The data in Table 1 summarize the results found in studying the involution rate of ruptured follicles and the number of ruptured follicles in relation to the number of eggs found. The data are arranged for the 2 years according to whether the last egg was found in the anterior, middle or vaginal end of the reproductive tract. It was assumed that the heaviest ovulated follicle in the ovary of the pheasant would be that one from which the egg in the anterior end of the oviduct had been ovulated. This assumption is based on the time required for the passing of the egg through the reproductive tract of the chicken (Warren and Scott, 1935).

RESULTS AND DISCUSSION

The data which show the rate of regression of ruptured follicles during the early part of the laying season in pheasants are recorded in Table 1 and graphically in Figure 1. The spaces in Table 1 in which follicle weights are not recorded are those days during which eggs were not laid. The average rate of regression in the weight of ruptured follicles, regardless of the position of the last laid egg in the oviduct, for the years 1943 and 1944 are given in Figure 1. Both the graph and the data in the table cover a period of 15 days after ovulation of the first egg. They show that the rate of regression is very rapid during the first 36 to 48 hours. Romanoff (1943) weighed a few ruptured follicles from the ovary of a pheasant and of a quail and also concluded that involution is rapid. During the period extending from the second to the fifth day the rate is slower, and by the seventh or eighth day regression has become extremely slow. At this time the remains of the ruptured follicle may have become reduced to a very small body weighing from 2 to 6 mgm. and which is often orange-yellow in color. These structures undergo additional regression after 15 days but persist for several months. From the data it appears that there is considerable variation in the weight of ruptured follicles supposedly involuting for the same length of time. These variations can be explained in part on the basis of findings in the common fowl in which it has been shown there is: (1) a difference in the size of the yolk at the time of ovulation (Jull, 1924), (2) a delay in ovulation following the oviposition of an egg in the afternoon (Scott and Warren,

1936), (3) a variation in the time elapsing between the laying of the previous egg and ovulation (Phillips, 1936). Another possible cause of variation in the weight of the ruptured follicles is the number of times the pens were examined daily for eggs, making possible an extreme error of 18 hours in estimating laying time.

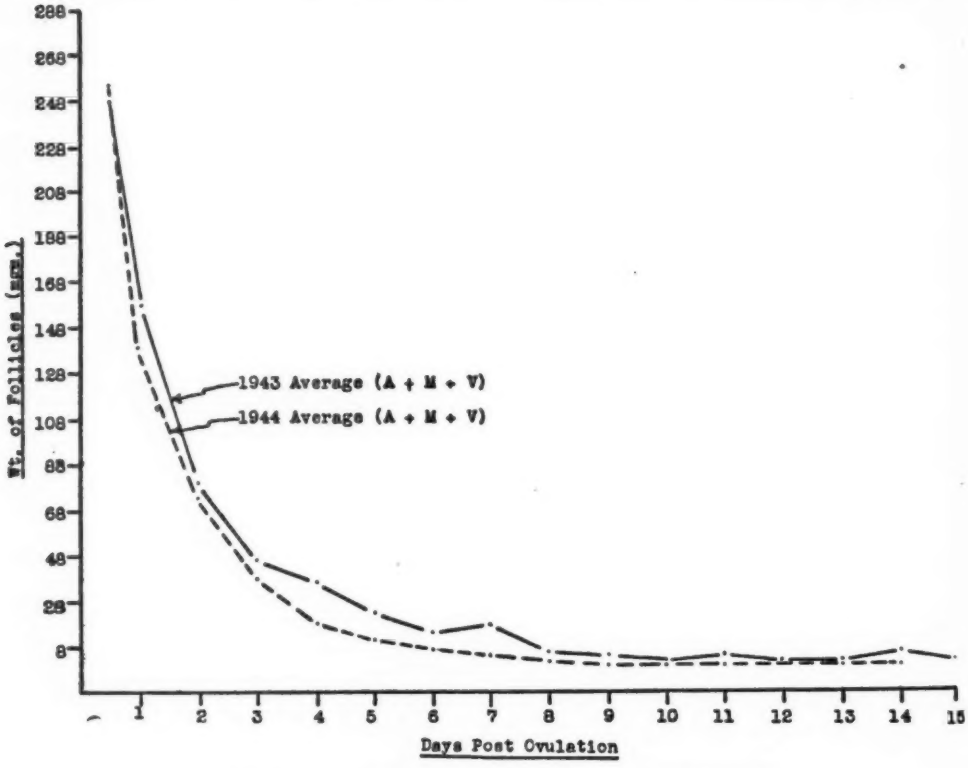


FIG. 1.—Regression of ovulated follicles in the pheasant.

The relationship between the number of eggs found and the number of ruptured follicles counted is recorded in Table 1 in the column headed "Ovulation follicle factor." Seven of the 50 factors determined were greater than, and 6 were less than 100. In the data collected for the year 1944 there were 3 factors above and 1 below 100. The occasions on which more ovulated follicles than eggs were found can be explained on the basis that: (1) some birds ate their eggs, (2) some eggs were ovulated into the body cavity and were not laid, and (3) follicles may involute without rupturing. This has been described for the South American cowbird by Davis (1642b). However, it is believed that the latter would account for only a small percentage of the cases in the pheasant. This belief is based on the examination of involuted follicles for remains of ovulation openings which in practically all cases are easily found in the follicles of the pheasant 15 days

after ovulation of the bird's egg.

The ovaries in which the ruptured follicle factor was less than 100 are more difficult to explain. There is a possibility that in certain cases follicles 12 to 14 days post-ovulation might involute to such a degree that no remains would be visible grossly; however, this is not probable. The majority of the cases in which the ovulation factor was less than 100 occurred in the 1943 experiment, at which time methods were being developed for the identification of ruptured follicles and it may well be that some of the smaller ones were overlooked. In the 1944 experiment there was only 1 follicle factor that was below 100. The data in Table 1 support the conclusions that the involuting ovulated follicles of the pheasant ovary can be used as: (1) a highly reliable indicator that eggs have been ovulated; (2) a method of determining the number of eggs ovulated, and (3) inferentially the number of eggs laid within a period 15 days after the laying of the first egg. In making these generalizations it is appreciated that every egg which is ovulated may not be laid, for, as indicated above, there is evidence that follicles may be ovulated in the body cavity and subsequently be resorbed. However, in these experiments with pheasants this was observed to happen but twice, and therefore would not be an important source of error. On the basis of the data collected in this investigation it seems probable that examination of the ovaries of pheasants collected in their natural habitat during the breeding season could be used to determine the number of eggs laid and the approximate day on which eggs had been laid within a period of 3 days before the death of the bird, as involution is rapid after this time.

SUMMARY

The post-ovulatory follicles of artificially-propagated pheasants involute rapidly within a period of 5 days after ovulation. Further involution is a very slow process and results in small pigmented structures which persist for at least 15 days post-ovulation.

The involuting post-ovulatory follicle provides a basis for determining ovulation rates in artificially-propagated pheasants during the breeding season and provides a method for studying ovulation rates in wild pheasants as related to population problems.

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MANAGEMENT SIGNIFICANCE OF DAMAGE BY GEESE AND MUSKRATS TO GULF COAST MARSHES

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The blue goose, the snow goose, and the muskrat are conspicuous among the wildlife of the coastal marshes of Louisiana and eastern Texas, and their economic importance is widely recognized. Blue and snow geese furnish sport for resident and visiting hunters, thereby contributing to the livelihood of hunting club operators and guides. The annual sporting kill of these geese in Louisiana and on the Texas coast above Galveston exceeds that of all other species of geese combined. In Louisiana some 10,000 trappers annually take 3,000,000 to 9,000,000 muskrats, and in East Texas about 500 trappers take 100,000 to 300,000.

Geese and muskrats are significant for other reasons. Local cattlemen and trappers complain that blue and snow geese damage cattle range and trapping lands, and trappers know that Louisiana muskrats sometimes "eat out" and destroy marsh land. These matters are not generally appreciated, although earlier writers (McAtee, 1910; McIlhenny, 1932) reported that wintering geese often create ponds in the marshes by feeding intensively on marsh plants, and other authors (Penfound, 1938; Russell, 1942) have suggested that muskrats might have important influence upon the ecology of Louisiana marshes.

Early in their 5-year study of waterfowl and fur management research on the Gulf Coast, the present authors found that damage to marsh was a normal consequence of the intensive feeding peculiar to blue and snow geese, and that similar damage inevitably resulted from overpopulation by muskrats. Both types of damage frequently became so widespread and serious as to disrupt programs of fur, wildlife, and cattle management. Disturbing the normal ecology and producing drastic changes in vegetation and physiography, geese and muskrats were obviously significant to marsh environments in a physical as well as a biotic sense. Some of the changes they wrought were desirable, and effort was made to exploit these potential contributions to management. More often the results of damage by geese and muskrats were inimical to profitable handling of marsh land, and an effort was made to determine how this damage could be circumvented, and how it could be repaired if control measures failed.

This report describes the manner in which geese and muskrats damage marsh lands, outlines the involved ecological changes that may follow such damage, summarizes the significance of such damage to the fur and cattle industries, and suggests control measures. Beneficial and harmful effects upon wildlife are indicated and evaluated from the standpoint of wildlife management.

GOOSE DAMAGE

Most of the blue geese (*Chen caerulescens*) of North America winter on the Gulf Coast between the Delta of the Mississippi River and Galveston Bay (Phillips, 1930). The lesser snow goose (*Chen hyperborea hyperborea*) is invariably associated with the blue goose on these wintering grounds. McIlhenny (1932) says there are few snow geese in southeastern Louisiana, but their numbers increase in the western part of the state. Blue and snow geese are equally numerous near the Sabine River, but the snow goose predominates in east Texas. As these geese are closely associated and their food habits in any given locality are identical, they are treated jointly here.

The easternmost winter concentration is on the Mississippi River Delta, and is estimated at about 300,000 birds, of which 5 per cent are snow geese. Normally they are found on three areas: (1) Cubitt's Gap subdelta (now in Delta National Wildlife Refuge), from the mouth of Main Pass to Pass-a-loutre; (2) Pass-a-loutre Crevasse, along the shores of Garden Island Bay between Pass-a-loutre and South Pass, on lands of the State of Louisiana Public Hunting Club; and (3) Bayou Baptiste Collette subdelta (used formerly by many geese, but oil development has discouraged recent use.)

McAtee (1910) listed some foods taken by blue and snow geese on the Mississippi Delta. Rhizomes and some seeds of three-square (*Scirpus americanus*) comprise the bulk of the food. The new deltaic flats where three-square makes its best growth must be lightly covered by water to enable geese to "puddle out" the rhizomes. When tides are low on the flats, geese move into the interior marshes, where rootstocks of cattails (*Typha latifolia* and *T. angustifolia*) become their principal foods. When early spring floods deeply inundate the flats and interior marshes, geese feed on rhizomes of dog-tooth grass (*Panicum repens;* locally called "Johnson grass") along the banks of old bayous. Should unfavorable feeding conditions continue for several weeks, many of the birds move north to Lake Athanasia, Bayou La Loutre, and Bayou Biloxi in St. Bernard Parish, near the Delacroix Island muskrat marshes.

Delta geese have been indicted by sportsmen for destroying duck foods, but present findings indicate that ducks actually benefit when geese tear up the three-square flats of the Mississippi Delta. Geese eat few of the three-square seeds relished by ducks; geese make available to pintails, baldpates, mallards and canvasbacks, rhizomes that these ducks could not otherwise get. When forced to feed on cattail and dog-tooth grass, however, geese destroy muskrat habitat. During the cold winter of 1939–40, geese devoured several square miles of cattail marsh on the Delta Refuge. This damage followed by a heavy freeze and a severe storm tide, caused the formation of numerous ponds; this represented a loss of muskrat marsh, but eventually proved beneficial for waterfowl. As a rule, geese produce distinct benefits to wildlife and do not compete seriously with muskrats and cattle on the Mississippi Delta. When these birds move into the St. Bernard Parish marshes, however, the congregate on the valu-

able muskrat marshes there and play havoc with trapping operations.

Blue and snow geese are strangely absent from the vast marshes of Lafourche and Terrebonne parishes. The foods preferred by geese are abundant in these marshes, but the only geese seen in the entire region were at Pointe au Fer, near Atchafalaya Bay. McIlhenny (1932) records occasional concentrations at Pointe au Fer and Morrison's Pass.

McIlhenny (1932) considers Marsh Island and the marshes of the mainland west to the Mermentau River the most important wintering ground of the blue goose, and aerial waterfowl inventories by the U. S. Fish and Wildlife Service substantiate this claim. Blue and snow geese are numerous throughout this region every winter, but the places of greatest concentration vary from year to year and are determined by water-levels and availability of food. The Rockefeller Refuge was the scene of a major concentration in the winter of 1938–39. During the dry autumn and winter of 1939–40, many left this region and moved westward. The 1940–41 season saw the greatest concentration on Marsh Island. The marshes from Cheniere au Tigre to Rollover Bayou harbored the greatest numbers during the winter of 1941–42, with the result that big cordgrass (*Spartina cynosuroides;* locally known as "hog-cane") and saltmarsh bulrush or "coco" (*Scirpus robustus*) of that region were literally laid waste, and much range of coastal cattle was temporarily destroyed.

Few geese use the marshes between the Mermentau River and Calcasieu Pass. West of Calcasieu Pass is another important wintering ground, which includes the Sabine National Wildlife Refuge, and the Oyster Bayou, Holly Beach, Peveto Beach, and Johnson Bayou marshes. Olney's three-square and "coco" are the principal goose foods here. This wintering ground extends along the coastal strip in eastern Texas as far as Galveston Bay; this paper is not concerned with the geese of the lower Texas coast. The eastern Texas marshes are higher and firmer than those of Louisiana, and geese feed on saltgrass (*Distichlis spicata*) rhizomes on the coastal cattle range as well as on the Olney's three-square and "coco" of the muskrat marshes. Blue and snow geese also feed extensively in the rice fields of Texas, although they are rarely seen in the Louisiana rice-belt.

Preferring rhizomes and other underground parts of marsh plants, blue and snow geese feed by grubbing; green foliage comprises less than 10 per cent of their winter food. Early in spring they graze more on new foliage of salt-meadow cordgrass (*Spartina patens*) and saltgrass in burned marshes, and upon smaller grasses and herbs of the coastal cattle pastures. These geese are powerful birds. The bill in both species is stout and tipped with a horn-like nail; the cutting edges of the mandibles, formed by the strongly developed lamellae, resemble coarse files. It would be difficult to improve upon McIlhenny's fine description (1932) of the manner in which the geese dig up their food; they are capable of grubbing out the toughest rhizomes of marsh plants, such as the fibrous rhizomes of "hog-cane" and southern bulrush (*Scirpus californicus*) in firm clay soils. The tuber-like rhizomes of "coco" are often so hard that they all but defy human

teeth, yet the geese cut them into several pieces before swallowing.

Geese have prodigious appetities. A single meal for one bird may involve a double handful of rhizomes, and the birds normally feed twice each day. A trapper, watching approximately 10,000 geese leaving their feeding ground, commented: "That's five acres of my rat marsh you see flying off." His remark was well founded, for the quantity of rhizomes carried away in the gorged stomachs of those geese probably would have been ample to replant five acres of marsh. Only clean rhizomes are found in stomachs, as the geese discard the tops and roots of food plants Plants not relished are pulled up and tossed aside in the search for more suitable foods. It is estimated that feeding blue and snow geese pull up and discard at least ten times the amount of plant material they actually consume.

Feeding flocks usually number from 100 to 1,500 birds and may include 10,000 geese. Congregations of thousands may occur prior to spring migration (McIlhenny, 1932) and during the winter under abnormal feeding conditions. One great flock near Oyster Bayou in Cameron Parish, Louisiana, during the dry autumn of 1939 numbered about 185,000 birds.

Many authors (Cottam, 1935; McAtee, 1910; McIlhenny, 1932; Soper, 1942) have described the feeding activities of blue and snow geese, which must be seen to be appreciated fully. It should be apparent, however, even to those unfamiliar with these birds, that thousands, feeding in the same area twice a day for several weeks, can produce radical changes in a marsh. Often the ground is completely denuded of vegetation (see Plate 4, A and B) and the soil may be broken to a depth of 5 to 8 inches before geese quit an area. The damaged marsh resembles land destroyed by muskrats. Trappers appropriately term such destruction by geese or muskrats as an "eatout." The dead marsh that results and which persists until recovery, is referred to as a "crevey" (French, *crevé*, dead or broken). These local terms are so descriptive that they are used in this paper.

MUSKRAT DAMAGE

The Louisiana muskrat (*Ondatra zibethicus rivalicius*) occupies marshes of the Gulf Coast from Mobile Bay in Alabama to Galveston Bay in Texas; its range extends inland to some river valleys and interior lakes (Lowery, 1936), and portions of the rice belt. Muskrats use various habitats, but are most abundant in three types of coastal marsh. Present discussion concerns these three types, of vital importance to the fur industry and most susceptible to damage by muskrats.

About 80 per cent of the annual muskrat catch of Louisiana and eastern Texas is produced on two types of brackish marsh, the most important being "three-cornered grass marsh," an association of Olney's three-square, salt meadow, and cordgrass or "wiregrass" (*Spartina patens*). Rhizomes and young shoots of the former serve as food, and "wiregrass" has some value as food, but is used more extensively for muskrat lodges or "houses." Three-square marsh is found at the head of normal Gulf tide action (Fig. 1 and 2). and is extensive throughout the coastal range of the muskrat. The plant grows

on highly organic peat soils. Muddy peats subject to admixture of clay from storm tides are taken over by "coco" marsh, an association of "coco" or saltmarsh bulrush, saltgrass, and "wire-grass." In southeastern Louisiana "coco marsh" is usually along the edges of or mixing with three-square marsh. In southwestern Louisiana and east Texas coco marsh forms extensive pure stands, particularly below Grand Chenier and Pecan Island and near Johnson Bayou (Fig. 2). "Coco marsh" produces many muskrats, but cannot sustain high populations for long periods as does three-square marsh. Coco grows little during the winter and cannot keep pace with the winter food demand of heavy muskrat populations. Three-square has a year-round growing season, retarded only temporarily by winter frosts.

FIG. 1.—Approximate extent of muskrat marshes in southeastern Louisiana. Three-square (*Scirpus olneyi-Spartina patens*) marsh is the principal marsh type in the areas marked in black. Fresh marsh (*Panicum-Typha*) is indicated by cross-hatching. Some of this fresh marsh has been reclaimed for farming.

Other plants in these two brackish marsh types include cattails, bulrushes (*Scirpus californicus* and *S. validus*), "sand rush" (*Fimbristylis castanea*), saltmarsh cordgrass (*Spartina alterniflora*), and several annual grasses and herbs. None of these is of great importance to muskrats in brackish marsh. Cattails and bulrushes are important muskrat foods elsewhere, but on the Gulf Coast they are used only in fresh-

water marshes where three-square is rare or absent. Stands of other vegetation around the margins of the best local muskrat marshes, identified by Penfound and Hathaway (1938) as zonal communities, include saltgrass, needlerush (*Juncus roemerianus*), reed and "cane" (*Phragmites communis* and *Spartina cynosuroides*), and shrubby growth (*Baccharis halimifolia* and *Iva frutescens*). The first of these communities is on saline clays, the second on muddy or sandy peats, and the others on bayou banks. These various plants normally have only limited value for muskrats, but canes and shrubs furnish emergency cover when the lower marshes are swept by storm tides. Furthermore the canes, saltgrass and needlerush marshes may be utilized by rats when better habitats become overpopulated.

The floating freshwater marsh of southeastern Louisiana is the only fresh marsh type consistently producing many muskrats (Fig. 1); cattails, bulrushes (*Scirpus californicus* and *S. validus*), and wapato (*Saggittaria latifolia*) are the principal food plants but maidencane (*Panicum hemitomon;* "paille-fine" or "canouche") eventually is the dominant plant. Other fresh and brackish marshes are utilized by muskrats to some extent, but rarely are subject to overpopulation and "eatout" except when all the adjacent better

FIG. 2.—Approximate estent of goose and muskrat marshes in southwestern Louisiana. Shaded areas represent brackish marshes. Three-square marsh predominates where numeral 3 appears; numeral 2 indicate coco marsh predominating. High brackish sea rim marshes used for cattle pasture are included in shaded portion.

marshes have been overpopulated.

It is general knowledge that muskrats can damage marsh vegetation, but difficult to believe that they can become abundant enough to destroy large tracts. Trappers' reports of such destruction were regarded with skepticism and discounted as propaganda for a longer trapping season, until the first instance of extensive muskrat damage was encountered personally. This paper will probably be considered propaganda by persons unfamiliar with the problems; therefore, the authors wish to make it clear that they are not advocating changes in the trapping regulations. Many instances of muskrat damage were studied during the past five years. The purpose in assembling these data is to point out that such damage has occurred, and will continue to occur so long as muskrat marsh is not properly handled. It is hoped that the findings of this investigation will help to prevent further damage and show how such damage can be repaired and utilized.

The Louisiana muskrat is strictly a marsh animal. Unlike the bank and pond rats in other parts of the country, this animal depends on the marsh for all of its food, shelter, and living space. It must build houses in the marsh because there is little high land suitable for "bank-holes" or "dens." Each house requires from one to 20 bushels of marsh vegetation; and its base, two to 10 feet in diameter, covers a portion of the marsh that would otherwise produce food plants. As the ponds and bayous of the Gulf Coast abound with alligators, gars, turtles, and other enemies, the muskrat shuns open water and confines normal movements to the marsh. The animal has surface trails for some of its feeding and a system of underground tunnels and plunge-holes for feeding in warm weather and during low tides. The muskrat makes exhaustive use of this habitat: its food and shelter decrease the supply of marsh vegetation; its trails and burrows cut up the marsh floor. Fortunately arsh plants grow rapidly in this latitude, and usually are able to keep pace with the normal food demands of the muskrat and to repair the damage caused by its burrowing. The muskrat is notoriously prolific. Detailed information on the reproduction of the Louisiana muskrat is not yet available, but the animal is known to have a year-round breeding season. Mature females can produce several litters each year, and the average number per litter is about four (Arthur, 1931). The animal has many natural enemies, but apparently predators do not seriously reduce high rat populations. Predators such as mink, raccoon, alligators, snapping turtles, and cottonmouth moccasins are now controlled by trapping and hunting. Prolonged droughts and peat fires destroy muskrats (Arthur, 1931), but these are infrequent in the Gulf Coast marshes. The loss of muskrats during floods and tropical storm tides is not so great as might be supposed, as canes, brush, and other tall vegetation enable many rats to weather storm tides and high water. Muskrats are subject to certain diseases, but these are usually the result of overcrowding and apparently do not assume epizootic proportions until populations threaten to exceed the carrying capacity of the marsh.

The carrying capacity of the muskrat marshes of this region varies greatly.

Some lands may produce one or two per acre. First-class marshes have produced 50 rats per acre each year for several successive years, and their carrying capacity must be considered in excess of this figure. Other lands have produced an even greater number, but on many of these the population had already exceeded capacity. The present authors do not intend to deal with the intricacies of carrying capacity, but only consider the obvious fact that rat populations tend to increase beyond the capacity of the marsh, regardless of what that may be. Natural factors alone frequently are inadequate to control this increase. Predators, disease, and other factors failed to hold populations within safe limits on an untrapped study area. Severe storm tides and floods and regular trapping were unable to avert overpopulation in many of the "eatouts" studied, particularly in the most extensive one observed.

Proper trapping is the only effective means of controlling rat populations. Overtrapping can and has occurred on the Gulf Coast, especially in the easily trapped marshes. The most valuable rat marshes are equally subject to undertrapping. Inadequate supervision, inefficient trappers, poor weather, and accidents contribute to under-trapping. Harvesting of heavy rat populations is not an easy task. The operator of large tracts of trapping land must have an intimate knowledge of his marsh and its problems, and must be adept at handling trappers. He must know his good trappers and place them where intensive trapping is needed. Unfortunately, he cannot be everywhere during the busy days before each trapping season and may have to trust his trappers to choose their own grounds. Many trappers are too ambitious, asking for more ground than they can cover; one may ask for a 300-acre trapping lot, reporting that it will produce 2,500 rats when he knows it should produce 5,000 during the coming season. He will be pleased to catch 3,000 rats and, if he does not expect to trap the same lot the next year, is not concerned that he has not removed enough to save the land from destruction. Two trappers on this area, taking 2,500 each, would share the revenue from the catch and save the land. Also trappers may be incapacitated during the season by sickness, injury, or snake-bite. Mosquitoes sometimes become so bad during the winter that trappers are forced to suspend operations for a week or two. Warm weather (Lay and O'Neil, 1942) and high water interfere with trapping, resulting in poor catches even where muskrats are extremely abundant. Many trappers become mentally and physically exhausted toward the end of the winter, and some leave the marsh when they could add several hundred rats to their total catch in the remaining weeks of the season.

When heavily populated marshes are not trapped, or are undertrapped, damage is inevitable. The length of time necessary for complete "eatout" cannot be predicted, being determined by many variables. One study area was not completely destroyed until four years after trapping was discontinued, yet a regularly trapped area was completely eaten out within three months after close of the trapping season of 1941–42. Both these cases are unusual; damage more often is progressive. If the trapper fails to reduce his rat population to safe

limits the first season after capacity is reached, the marsh may become overpopulated the following summer and be so badly cut up by feeding rats that proper trapping is virtually impossible the next season. Trappers shun partially damaged marsh because it is extremely difficult to walk and because good trap sets are hard to find in the maze of old burrows and trails. Complete "eatout" usually occurs the second summer in such cases after population exceeded capacity.

The first signs of "eatout" can be detected only by an experienced observer. Marshes carrying normally heavy rat populations are honey-combed with underground tunnels and surface trails. When the number of rats increases to the danger point, the tunnels are cut into open canals (see Plate 4, C and D). Widening of surface trails and haphazard digging become more prevalent, cutting the marsh floor until the area is only a series of small islets of vegetation (see Plate 5, B). The marsh near rat houses is the first to be completely denuded of vegetation (see Plate 5, A). As the "eatout" becomes advanced, the remaining islets of vegetation are attacked from the tops and edges and are undermined by the rats. Finally the "eatout" becomes a sea of mud. Rat houses appear strangely massive when no vegetation remains to hide them. Plant stalks and discarded roots are trampled into the muck, save for a few tufts sticking up at odd angles. Plants on the larger tufts of sod seem to have escaped damage, but closer inspection shows that most of the plants are dead stalks from which the roots were cut when the sod was undermined.

Their food exhausted and their habitat destroyed, rats must find new marsh or perish. Sick rats and females with young cannot move far and may remain in the "eatout" to glean what little food is left. Such rats are commonly seen during the day, wallowing through the muck of the "eatout." This is extraordinary behavior, for Louisiana muskrats normally are nocturnal. Strong healthy rats leave the "eatout." Sometimes the exodus is imperceptible and continues for months. The migrants seem not to move far, accepting any undamaged marsh as a temporary home. In other cases sudden mass migrations occur. The broad trails or "roads" made by rats evacuating the "eatout" are spectacular features of such migrations. The escape roads, unlike normal feeding trails, are wide and comparatively straight and run over rather than around obstacles. Roads often are paved with a thick layer of mud, brought from the damaged marsh on the feet and belly-fur of the fleeing rats. Carcasses of rats killed by predators and in fights litter the paths of escape. Possibly some trait of animal psychology akin to mob impulse is involved in these mass migrations, because rats from parts of the marsh that are not completely destroyed often join in the general exodus.

ECOLOGICAL CONSEQUENCES OF DAMAGE

Goose and muskrat "eatouts" disturb the normal ecology of a arsh, just as burning, cutting of timber, and plowing are disturbances in the natural plant successions of grasslands or forests. Some "eatouts" are inevitable and others may occur despite control measures, hence the marsh manager

must appreciate their significance to succession in the marsh vegetation and be familiar with the factors that influence their repair. It is appropriate, therefore, to outline briefly the stages in normal succession of marsh vegetation and indicate the consequences of disturbance to this normal succession. This information is summarized in the accompanying chart (Fig. 3), and each stage is discussed in greater detail below the same numeral or letter assigned it on the chart.

1. NORMAL PLANT SUCCESSION

The muskrat marshes, including three-square marsh (*Spartina patens-Scirpus olneyi* association), "coco marsh" (*Distichlis spicata-Spartina patens-Scirpus robustus* association), and fresh marsh (*Panicum hemitomon-Typha* association) are characterized by peaty soils. The process of peat formation cannot elevate these soils above the average low water level, as further accumulation is consumed by slow oxidation or by natural and incendiary fires during dry weather. Fires prevent establishment of trees and other woody vegetation. The eventual grass dominance apparent in these various peaty marsh types may therefore be considered an edaphic climax. Geese feed in the peaty muskrat marshes to a considerable extent but are partial to the firm clay-soil marshes near the shores of the Gulf in southwestern Louisiana and eastern Texas. The soils of the latter are maintained and sometimes elevated by clay deposits from storm tides. Theoretically, plant succession there would proceed towards a tree climax. (Penfound and Hathaway, 1938). These storm deposits, however, are insignificant on many goose ranges, and in other regions are just sufficient to compensate for coastal subsidence. Only on beach ridges do they build land high enough for trees to grow. These ridges comprise a small part of the extensive "high marsh" so significant to goose and cattle management. For practical purposes, therefore, we may consider grass dominance to indicate an edaphic climax in these clay-soil marshes. The stages of normal plant succession are similar in the peat and clay-soil marshes.

1-A. *Open ponds.* Ponds are conspicuous features of the coastal marshes. Some are affected by tide action; others are closed. Small ponds are created by geese, muskrats, peat fires, alligators, hurricanes, and by human agencies. Larger ponds and lakes usually represent geologic or physiographic formations. Ponds are valuable in varying degree for waterfowl, fur animals, and other wildlife. Marsh ponds having peaty or trashy bottoms, and tidal ponds with radical water fluctuation have limited value. Geese occasionally roost in such ponds, and some ducks, including the gadwall, shoveller, baldpate, and teal, feed there. Ducks subsist largely on animal foods such as fish, crustaceans, and mollusks in tidal ponds, as growth of submerged aquatic plants is inhibited by water fluctuation and turbidity. Wigeongrass (*Ruppia maritima*) and pondweed (*Potamogeton foliosus*) grow in the better tidal ponds.

Marsh ponds with soft clay or firm muck bottoms may be highly productive. Brackish ponds of this type offer a variety of duck food plants, including sago pondweed (*Potamogeton pectinatus*), wigeongrass, pondweed (*P. foliosus*), naiad (*Naias guadalupensis*), and ba-

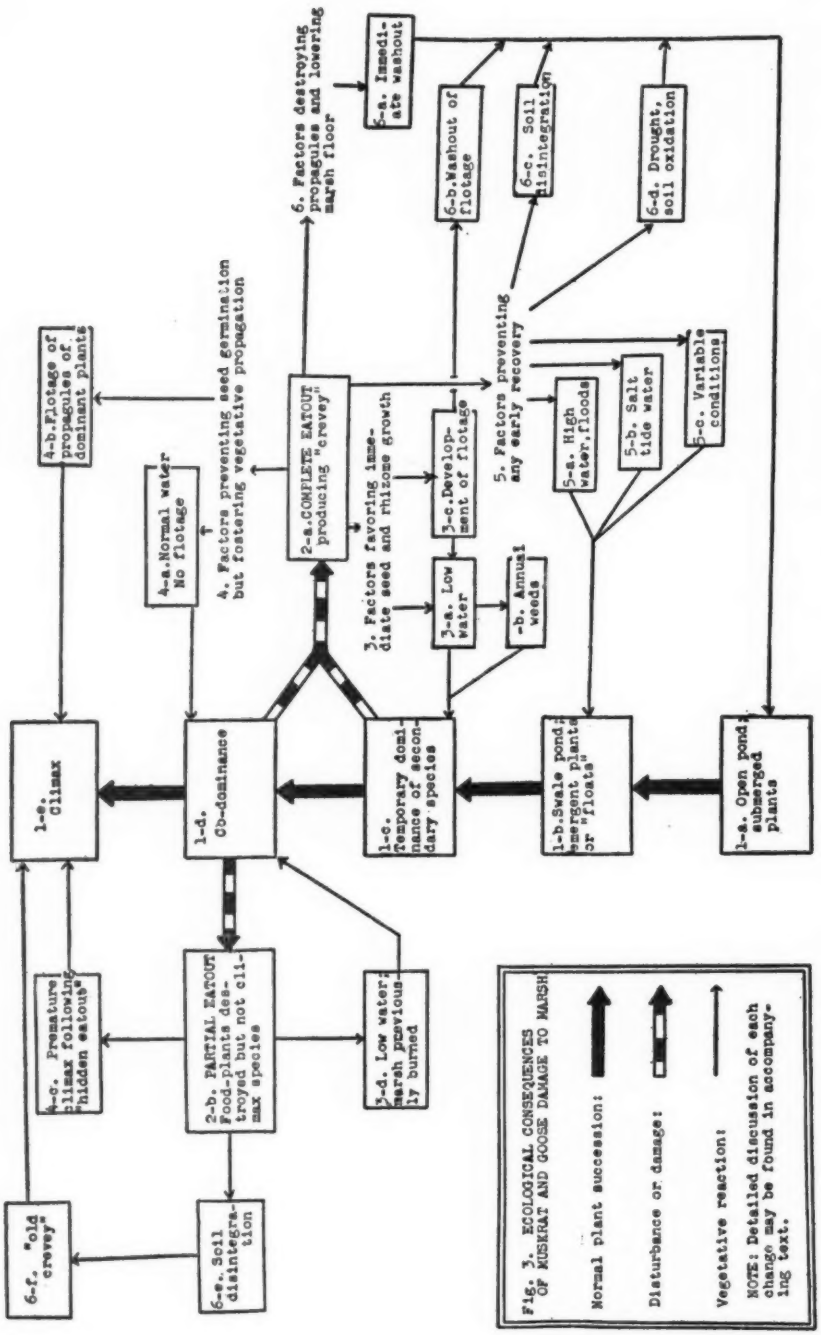

1-a. Open pond; submerged plants
1-b.Swale pond; emergent plants or "floats"
1-c. Temporary dominance of secondary species
1-d. Co-dominance
1-e. Climax
2-a.COMPLETE EATOUT producing "crevey"
2-b. PARTIAL EATOUT Food-plants destroyed but not climax species
3-a. Low water
-b. Annual weeds
3-c.Development of flotage
3. Factors favoring immediate seed and rhizome growth
4-a.Normal water No flotage
4-b.Flotage of propagules of dominant plants
4. Factors preventing seed germination but fostering vegetative propagation
5-a. High water,floods
5-b. Salt tide water
5-c. Variable conditions
5. Factors preventing any early recovery
6. Factors destroying propagules and lowering marsh floor
6-a. Immediate washout
6-b.Washout of flotage
6-c. Soil disintegration
6-d. Drought, soil oxidation
6-e. Soil disintegration
6-f. "old crevey"
3-d. Low water; marsh previously burned
4-c. Premature climax following "hidden eatout"
Fig. 3. ECOLOGICAL CONSEQUENCES OF MUSKRAT AND GOOSE DAMAGE TO MARSH
Normal plant succession:
Disturbance or damage:
Vegetative reaction:
NOTE: Detailed discussion of each change may be found in accompanying text.

FIG. 3.—Ecological consequences of muskrat and goose damage to marsh.

nana waterlily (*Nymphaea mexicana*). Fresh ponds produce many of these plants and a variety of other aquatics, including watershield (*Brasenia schreberi*), white and blue waterlilies (*Nymphaea odorata, N. tuberosa,* and *N. elegans*), coontail (*Ceratophyllum demersum*), and the submerged form of delta duckpotato (*Sagittaria platyphylla*). These clean ponds are used by all the wintering ducks. It is important to recognize the difference in value between clean ponds and those that are trashy or subject to tide action, since either type may result from goose or muskrat "eatouts." Ponds created by geese on the clay-soil marshes usually are productive. "Eatouts" in peaty marsh often result in trashy ponds that are unproductive until their bottom oozes are flushed out by storm tides or become compacted by temporary drying of the pond. Ponds that form in peaty marsh near the coast often become subject to tidal action. Rain and tide waters trapped in an original "eatout" cut drainage channels in the soft soils of the damaged marsh. These channels become part of the natural drainage pattern of the marsh and cause such radical fluctuation of water levels that the ponds become relatively barren of submerged vegetation.

1-B. *Swale ponds.* Small marsh ponds may be filled by accumulation of plant debris and by tidal deposits. Submerged aquatic plants are followed in the normal plant succession by floating-leaved aquatics, and these give way to emergent plants when the pond becomes sufficiently shallow. Often emergent plants such as cattail and bulrush invade shallow ponds during extreme low water. Once established, these emergents dominate submerged vegetation and assume a major role in building up the pond bottom to the level of the surrounding marsh. Bottom ooze of deeper ponds often floats to the surface of the water, and is immediately colonized by emergent and marsh plants. Russell (1942) points out that formation of "flotant" has been accelerated since the introduction of the exotic water-hyacinth (*Eichhornia crassipes*) and alligator-weed (*Alternanthera philoxeroides*), which cause the fresh marshes of southeastern Lousisiana to encroach more rapidly upon open water. Other mat-forming plants of fresh marshes include water smartweed (*Polygonum portoricense*), frogbit (*Limnobium spongia*), water parsley (*Hydrocotyle ranunculoides*), and waterlettuce (*Pistia stratiotes*). Swale ponds are used by mallards and pintails, but are not attractive for divers or ducks that prefer open ponds. Alligators, raccoons, and otters find favorable habitat in swale ponds.

1-C. *Dominance of secondary perennials.* When the marsh floor is sufficiently elevated, species representing the final plant associations appear. The secondary plants of the various associations under discussion are fast growers and able to spread rapidly by vegetative propagation and by seed. The eventual dominants of the associations have slower rates of growth; and as their spread is dependent largely on the slow process of vegetative reproduction, it may take years for them to assume dominance. Thus three-square may assume temporary dominance in the *Spartina patens-Scirpus olneyi* association (see Plate 5, C), and coco and cattail will form solid stands in marshes

representing respectively the *Distichlis spicata-Spartina patens-Scirpus robustus* and the *Panicum-Typha* associations.

1-D. *Codominance.* Marshes where secondary plants predominate or are codominant with climax species are most productive of waterfowl and muskrats. The secondary plants of the associations under discussion are the food plants for geese and muskrats. Competing with these food plants are their dominants, such as saltmeadow cordgrass (see Plate 5, D), saltgrass, and maidencane. As establishment of dominants becomes advanced, the carrying capacity of the marsh for waterfowl and muskrats is lowered. Marsh management seeks to discourage the invasion and spread of dominants, thereby encouraging production of food plants. Careful burning (Lynch, 1941), is the most effective means of controlling marsh vegetation. Fall burning in *Spartina-Scirpus olneyi* marsh removes the cordgrass (*Spartina*) canopy and allows the fast growing three-square to dominate the area temporarily. "Coco marsh" and fresh marsh (*Panicum-Typha*) are sometimes burned in the autumn to facilitate trapping, but in many regions these types are burned in late winter, just before the start of the spring growing season for their respective food plants.

1-E. *Climax.* Should any of these marsh types remain unburned for a period of years, their dominants tend to overwhelm secondary plants and produce an edaphic climax. The time required is determined by the degree to which dominants have become established when regular burning is stopped. Solid stands of secondary plants may persist for years despite the fact that they are protected from fire. Mixed stands with well established dominants reach climax in one to three years if unburned. Climax marsh, appropriately called a "rough," is comparatively worthless for waterfowl and muskrats. Climax wiregrass creates an especially bad rough. Winter winds prostrate the rank growth of this plant after each growing season. After two or three years a heavy mat of old grass forms on the marsh floor. Culm nodes root into this slowly decaying litter, so that the wiregrass elevates its root horizon each succeeding year. The worst wiregrass rough observed during these studies was in the Ely Ridge section of Cameron Parish, Louisiana, in marsh unburned for eight years. The 2-foot mat underlying this rough could support a man's weight; and the rank new growth of the current season, higher than an average man, had overwhelmed all other vegetation in the vicinity, including bulrush (*Scirpus californicus*). Climax marsh of this sort can be removed only by a hot fire during a dry season (see Plate 6, A). Regular burning of muskrat marshes now prevents widespread formation of heavy roughs. Presumably, before the advent of man, many marshes periodically developed worthless climax roughs and returned to productivity only after severe natural fires.

2. GOOSE AND MUSKRAT DAMAGE

As already noted, goose and muskrat "eatouts" disturb the normal ecology of the marsh. Destruction of vegetation brings about adjustments in subsequent plant associations. Soils are changed physically by breakage, and chemically by decomposition, reduction, and increased bacterial activity.

The physiography of the land may be altered by reorganization of drainage patterns.

2-A. *Complete "eatout."* This usually occurs in marsh where food plants temporarily dominate climax species. Solid stands of three-square, "coco," and cattail are more liable to destruction by geese or muskrats than are mixed stands containing a large proportion of climax plants. The marsh is denuded of vegetation by complete "eatout" (see Plate 6, B). The marsh floor may be broken up to a depth of eight inches when geese have caused the damage, and as deep as 20 inches in areas damaged by muskrats. Soils of damaged marsh disintegrate into loose muck with decaying plant discards and occasional turfs of undermined marsh sod. The resultant "crevey" may become revegetated in a single growing season, but more often it persists for several years. Some forms of wildlife are attracted to damaged marsh, but geese, muskrats, and cattle usually shun such areas.

2-B. *Partial "eatout."* When secondary and climax plants are equally abundant, partial "eatout" is likely to occur. Muskrats or geese may consume all the three-square in *Spartina-Scirpus* marsh without destroying the cordgrass. Geese caused most of the partial "eatouts" studied. Changing water levels, hunting, and other factors may force geese to move from a feeding ground before it is completely destroyed. Muskrat damage usually results in complete "eatout," especially on highly productive marsh. Occasionally muskrats may be killed by storms and floods or will migrate or be trapped out of a damaged marsh before complete "eatout" occurs.

Partial "eatouts" on regularly burned lands differ from those in unburned marsh. Food plants remain active on burned marsh and continue to produce the seeds and other propagules needed to revegetate the area. When such an area is damaged by geese or muskrats temporary wildlife habitat may be created, and the usually rapid recovery soon returns the marsh to productivity. Unburned marsh is subject to a more serious form of damage. Climax plants on unburned marshes dominate marsh vegetation, reducing the supply of food plants and the carrying capacity of the marsh. Geese seldom feed in unburned marsh, but muskrats remain until their food supply is exhausted. Trapping becomes increasingly difficult as climax roughs accumulate, and rat populations increase while the carrying capacity is progressively lowered. The result, called by trappers a "hidden eatout," is a premature climax marsh that is not only worthless for years to come, but may take decades to become rehabilitated (see figure 3, 4-C).

3. FACTORS STIMULATING IMMEDIATE RECOVERY

Recovery of damaged marsh is influenced by many factors. The quantity of seeds and other propagative bodies surviving the "eatout" is of primary importance. Most perennial marsh plants can reproduce by means of rhizomes. Many rhizomes of climax plants, such as wiregrass, survive goose and muskrat damage; they are not eaten extensively but they may be pulled up in feeding. Some rhizomes of food plants also survive "eatouts," despite the quantities consumed. Geese are wasteful feeders, selecting the

youngest and most tender rhizomes. Muskrats exhibit a similar preference and discard old fibrous rhizomes, many of which are still viable. These surviving rhizomes remain alive for several months, buried in the muck of the "crevey." If conditions immediately after "eatout" are favorable for their growth, repair of damaged marsh is rapid.

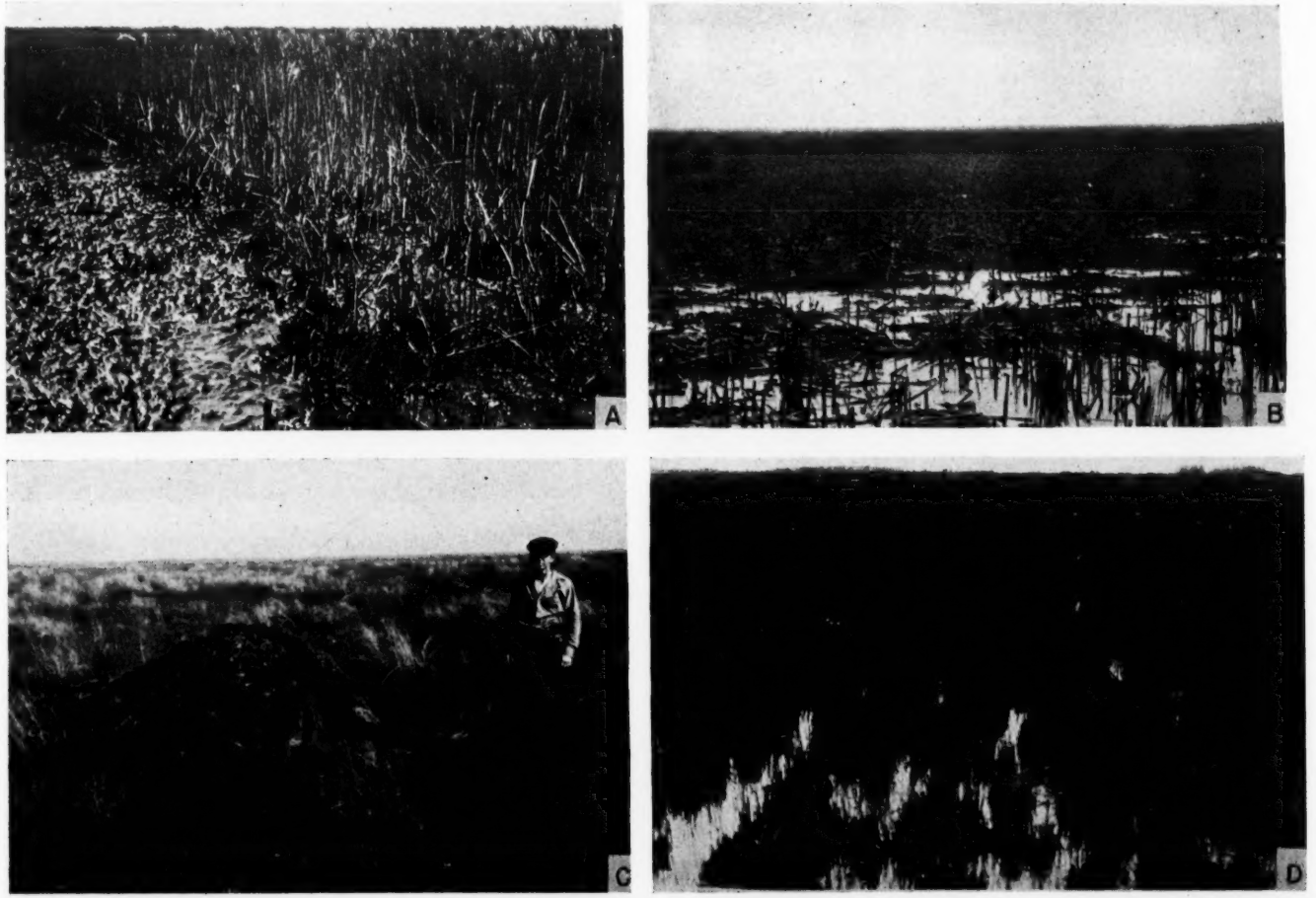
Seeds of marsh plants also assist in repair of damage. How long seeds of various marsh plants can remain viable, is unknown; but seeds of some species, particularly the *Scirpus* group, withstand prolonged dormancy. These seeds are eaten only to a limited extent by geese, and not at all by muskrats. Therefore seeds representing the accumulation of several growing seasons lie in the muck of the "crevey," awaiting conditions favorable for germination. Ducks that use new "creveys" feed on these seeds. Exact information on the extent to which ducks deplete the supply is lacking, but we think significant amounts were consumed by ducks in some study areas, causing delay in revegetation.

In the recovery of "eatouts," seeds of food plants such as three-square, "coco," and cattail, germinate readily when conditions are favorable. Climax plants rarely reproduce from seed in our marshes, depending almost entirely on vegetative propagation. The seeds of all emergent marsh plants under discussion remain dormant under water and must be emersed before germination takes place.

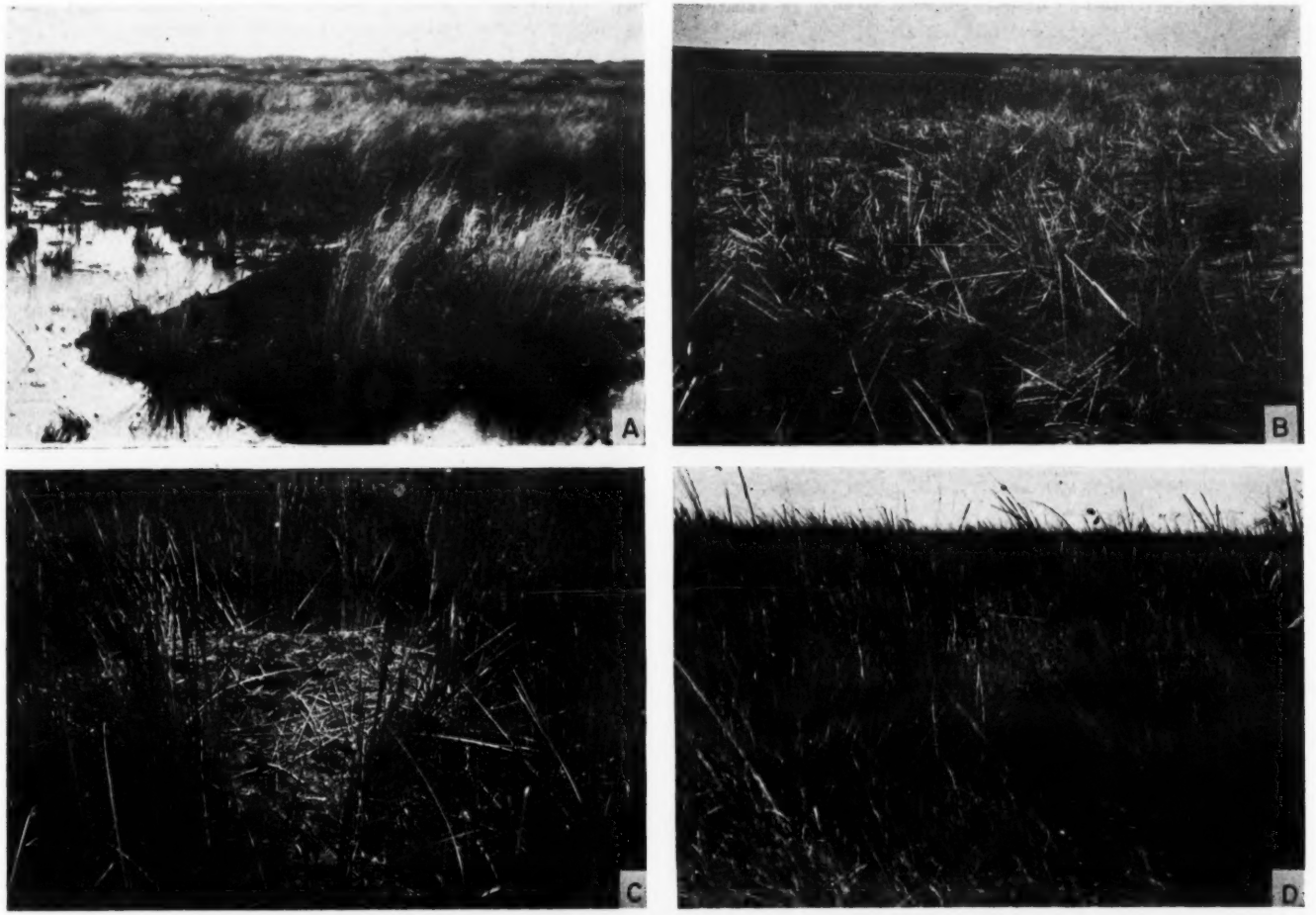
3-A. *Low water.* Low tides and dry weather foster immediate repair of the "crevey," stimulating both seed germination and rhizomes recovery. Artificial drainage of the "crevey" produces the same result. Trappers often cut small ditches in damaged marsh to drain out surface water during low tides. In several of the "eatouts" studied, drainage immediately after damage enabled normal vegetation to become reestablished in one growing season.

Revegetation is only the first step in repair of a "crevey," even when the new growth has obliterated all surface evidence of damage. When marsh is damaged by geese or muskrats, the roots that bind marsh soils into firm peat are destroyed and these soils disintegrate (see Plate 6, C). New vegetation will produce a thin sod on the surface of broken soils, but the underlying ooze remains so soft that muskrats are unable to dig burrows and plunge holes. The substratum in clay-soil marshes usually is soon repaired, but it may take years for plant roots to rebind loose soils of "eatouts" in peaty marsh into the firm turf that the muskrat demands.

3-B. *Annual weeds.* Seeds of many annual plants are distributed by tides and lie dormant in marsh soils, awaiting a chance to germinate. Normally these annuals have little chance to grow, because they are shaded by the canopy of perennials. When this canopy is removed by goose or muskrat damage, the annuals quickly occupy the "eatout" if water levels are low enough during the spring to permit seed germination. This explains in part the sudden and often spectacular appearance of annual grasses and herbs in the coastal marshes. These annuals include many important waterfowl food plants such as wild millet (*Echinochloa walteri*), waterhemp (*Acnida alabamensis*), sprangletop (*Leptochloa fascicularis*), fall pani-



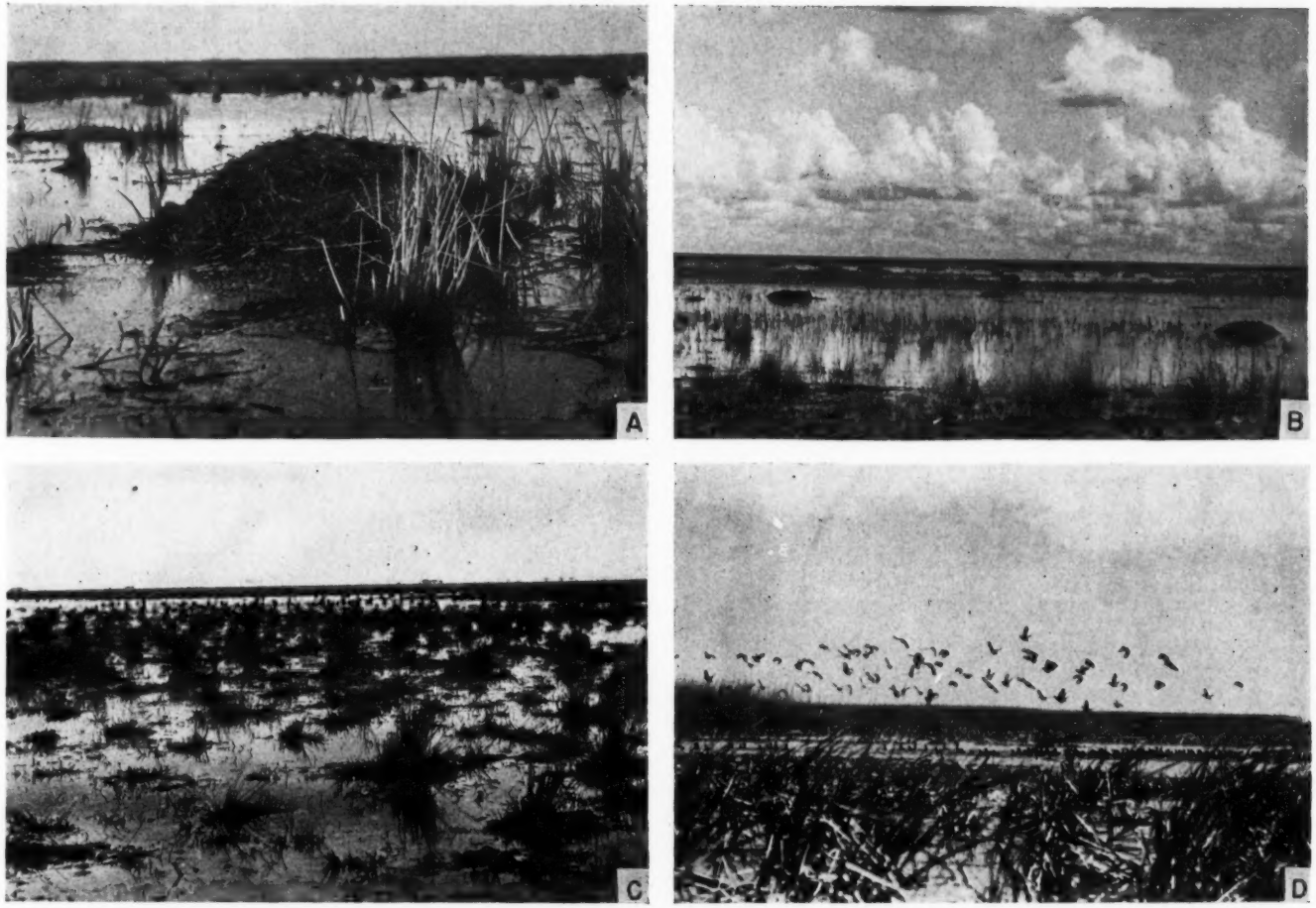
A. Goose damage to three-square (*Scirpus olneyi*) marsh. Vermilion Parish, La., December 1941. *B*. Goose damage to "hog-cane" (*Spartina cynosuroides*) marsh. Vermilion Parish, La., December 1941. *C*. Normal muskrat marsh (*Spartina-Scirpus*) after burning. Cameron Parish, La., November 1938. *D*. Three-square marsh being cut by heavy muskrat population. Vermilion Parish, La., March 1941.



A. Marsh in vicinity of muskrat houses is first to be completely denuded by "eatout". Iberia Parish, La., April 1941. *B.* Three-square marsh being undermined by muskrats. Iberia Parish, La., December 1941. *C.* Solid stand of three-square, representing dominance of secondary perennial in *Spartina-Scirpus* association. Iberia Parish, La., April 1941. *D.* Three-square and cordgrass in co-dominance. Cameron Parish, La., October 1939.

A. Cordgrass rough removed by fire. Note destruction of marsh floor by hidden eatout. Cameron Parish, La., November 1939. *B*. Complete "eatout" by muskrats. Vermilion Parish, La., August 1943. *C*. Trashy soils and plant debris that render ponds resulting from "eatouts" unproductive. Vermilion Parish, La., August 1938. *D*. Flotage of soil and plant debris hastens seed germination in eatouts. Iberia Parish, La., April 1941.

Square marsh being undermined by muskrats, Iberia Parish, La., December 1941. *C*. Solid stand of three-square, representing dominance of secondary perennial in *Spartina-Scirpus* association. Iberia Parish, La., April 1941. *D*. Three-square and cordgrass in co-dominance. Cameron Parish, La., October 1939.



A. Goose damage to muskrat marsh, showing destruction of habitat and trapping sets. Vermilion Parish, La., April 1941. *B*. Goose damage to heavily populated muskrat marsh precipitated this muskrat "eatout". Vermilion Parish, La., August 1943. *C*. Coastal cattle range damaged by geese. Vermilion Parish, La., April 1941. *D*. Pond coots in cattail marsh damaged by geese. Plaquemines Parish, La., June 1939.

cum (*Panicum dichotomiflorum*), sedges (*Cyperus*), and marsh indigo (*Sesbania macrocarpa*). Other annuals, including giant foxtail (*Setaria magna*), wild balm (*Pluchea purpurascens*), *Samolus floribundus*, and others, may appear in the "crevey" during dry summers and are frequently found on old muskrat houses. Several perennial weeds also are found in new "creveys." Of these, the spikerushes (including *Eleocharis parvula*, *E. palustris*, and *E. cellulosa*), are important as waterfowl foods. Other perennial weeds such as salt marsh aster (*Aster subulatus*) are worthless. Many species of ducks are attracted to "creveys" when annual food plants appear. Muskrats eat the basal parts of wild millet. Millet can be planted in "creveys" for duck food if water levels are controlled. Annual weeds die in winter and hence do not seriously retard reestablishment of perennials. Often these weeds assist in repair of "creveys" by securing loose soils against storm washout until normal perennial vegetation is restored. Waterfowl food plants are produced in greatest abundance and variety in goose "eatouts" in clay-soil marshes. Dwarf spikerush (*Eleocharis parvula*) is about the only duck food plant that consistently appears in peaty marshes after "eatout."

3-C. *Development of flotage.* Seeds of our marsh plants must be emersed to germinate, but masses of flotage often appear in new "creveys" (see Plate 6, D) that are filled with water. These represent plant debris and soils from the broken marsh floor. Decomposition gases accumulate under this material and lift it to the surface of the water. Seeds carried up in this flotage are able to germinate. In April 1942, 18 "coco" seedlings per square foot were found on flotage after serious goose damage to the marshes near Mulberry Island, Louisiana. These seedlings consolidated the loose flotage into sod so quickly that a subsequent storm tide was unable to dislodge it (see 6-B).

3-D. *Low water following partial "eatout."* Much of the original vegetation survives in partial "eatouts" caused by geese in regularly burned marsh. Such "eatouts" are healed quickly by spread of surviving plants and by seed and rhizome recovery when conditions are favorable. This type of damage may be completely repaired in a single growing season, and the new vegetation usually is similar to that of the original marsh (see 4-C for unburned marsh).

4. SEED GERMINATION VS. VEGETATIVE PROPAGATION

Water levels following "eatout" may remain too high for seeds to germinate, and recovery must be accomplished by vegetative propagation.

4-A. *Normal water levels.* The secondary plants of the various marsh associations are at a disadvantage when their recovery is limited to vegetative propagation. As they are the food-plants of geese and muskrats, a large proportion of their rhizomes (their only means of vegetative propagation) is consumed. Rhizomes that survive "eatout" will not remain viable indefinitely, but will die if soil and water conditions after "eatout" do not favor their immediate growth. To survive, rhizome fragments of three-square, "coco," and cattail must establish growth within 5 months after "eatout." Given favorable conditions, these rhizomes will enable food plants to keep pace with climax species

B. Goose damage to heavily populated muskrat marsh precipitated this muskrat "eatout". Vermilion Parish, La., August 1940.
C. Coastal cattle range damaged by geese. Vermilion Parish, La., April 1941. *D.* Pond coots in cattail marsh damaged by geese. Plaquemines Parish, La., June 1939.

in recovery, and the marsh will be productive when fully repaired.

4-B. *Normal or high water with flotage of propagules of dominants.* Unfavorable conditions may persist in the "crevey" until all the rhizomes of food plants die. Rhizomes of climax plants are longer-lived, but these cannot withstand prolonged dormancy. When recovery is delayed beyond the period of viability of all surviving rhizomes, revegetation may be accomplished by sprouts from culm-nodes or "joints" of grasses. This method of propagation is peculiar to climax grasses, including cordgrass, saltgrass and maidencaine. Culms of these grasses are cast aside by geese and muskrats and form mats in damaged marsh. When these mats float to the surface of the water, every culm-node becomes a propagule. Cordgrass culms have been found sprouting at the nodes after dormancy of 20 months, indicating their resistance to decay. When recovery is accomplished by this process, climax marsh is produced. Valuable three-square grass marshes have been replaced by worthless climax roughs in the majority of muskrat "eatouts" studied.

4-C. *Premature climax following partial "eatout" in unburned marsh.* The "hidden eatout" (2-B) that may be caused by muskrats in unburned marsh has been described. This type of damage, which may be unnoticed by those unfamiliar with muskrat marsh because the land is not denuded of vegetation, produces a climax marsh similar in appearance to that described in 4-B. There is one significant difference. Normal mature climax marsh grows on a level marsh floor and produces prostrate mats that can be removed by fire, allowing food-plants to reinvade. The climax produced by a hidden "eatout" is premature. Muskrats can dig up all the three-square in unburned *Spartina-Scirpus* marsh, leaving clumps of cordgrass. This cordgrass produces an erect rather than prostrate growth, eventually forming "niggerheads." Cordgrass niggerheads only 8 inches across at the base may produce a canopy shading out all other vegetation within a radius of 4 feet. Such a marsh is worthless for fur and wildlife. It can be rehabilitated only by extremely hot fires in times of drought, as the vegetation is too discontinuous to carry a normal cover fire.

5. FACTORS PREVENTING ALL RECOVERY, BUT NOT IMMEDIATELY AFFECTING MARSH FLOOR

Certain soil and water conditions may prevail in "creveys" so long that revegetation is delayed for years.

5-A. *High water or floods.* Prolonged high water in damaged marsh prevents seed germination and may delay vegetative propagation until all rhizome fragments and culms have died. The "crevey" may persist for years as a shallow pond. Cattails and other emergent plants invade the pond when it goes dry, and bordering vegetation slowly invades shallow parts of open water areas.

5-B. *Salt water.* Storm tides may throw salt water into the "crevey" before recovery is started. This salt water is concentrated by evaporation during dry weather, often becoming strong enough to destroy vegetative propagules. Dormant seeds can withstand high salinities, but are unable to germinate until salts are leached out of surface soils by rains or freshwater tides.

Shallow ponds or "salt scalds" result when "creveys" remain filled with salt water for long periods.

5-C. *Variable factors.* Marsh environments are subject to constant change. Plants that have started to recover from damage may have to endure a succession of unfavorable circumstances. Seedlings and other new growth may be killed by floods, droughts, or salt tides. Geese and muskrats sometimes return to "creveys" and destroy new vegetation before it becomes fully established. These factors may exhaust all propagules, so that revegetation may be delayed until tides bring a new supply of seeds into the "crevey."

6. FACTORS DESTROYING PROPAGULES AND LOWERING MARSH FLOOR

The swale ponds already described as resulting from "eatout" are quite shallow, and their bottoms may be little lower than the level of the surrounding marsh. Deeper, more permanent ponds are formed by the following:

6-A *Immediate storm washout.* Marshes that have undergone complete "eatout" are susceptible to washout by storm tides. Outlying marshes may be covered at any time of year by high tides. Highest tides occur during the hurricane season from August through October. With every tropical storm in the Gulf of Mexico, 3 to 5 foot tides and strong winds are felt along the Gulf Coast, and marshes in the direct path of a hurricane may be flooded to a depth of 10 feet (Cline, 1926). When storm tides sweep over the marsh, loosely anchored soils and vegetation are liable to be torn loose and washed away. Russell (1942) states that Wonder Lake, a water body about 1½ miles long in southeastern Louisiana, was formed by washout during a hurricane in 1915. A moderate tropical disturbance in August 1940, enlarged many old ponds in the marshes of the Mississippi Delta and created a number of new ponds by washing out cattail marsh damaged by geese during the previous winter. This storm incorporated seven ponds on the Delta National Wildlife Refuge into one large lake.

No major tropical storms have struck near the study areas during the past 5 years. Several moderate disturbances have occurred during this period, and offshore storms of greater intensity have caused high tides and strong winds. Though the authors have not personally observed the effects of a major hurricane upon marsh damaged by geese and muskrats, there can be no doubt that "eatouts" in the direct path of such a storm would be subject to extensive washout. The great Worm Bayou "crevey" on Marsh Island, Louisiana, was probably formed in this manner. Storms of lesser intensity have not produced the washouts anticipated. Repair of goose "eatouts" commences early in spring and usually is sufficiently advanced by the start of the hurricane season to secure loose soils against washout. Muskrat "eatouts" that occurred in summer would undoubtedly be washed out if swept by storms that same year. Such "eatouts" are relatively immune to washout the second year after damage, because by that time their soils have become waterlogged, settled, and consolidated in part by new vegetation. The authors' observations indicate that minor storms must occur immediately after "eatout" to produce ponds, although any unre-

paired portions of older "creveys" might be washed out by a major storm.

6-B. *Washout of flotage.* It takes 3 to 10 weeks for the flotage described in 3-C to be bound by roots of new vegetation. High tides or flood rains and heavy winds may break up flotage and wash it out of the "crevey" during this critical period. Such washout destroys seedings and rhizomes and deepens the "crevey" by removing loose soils and plant detritus.

6-C. *Soil disintegration.* Older "creveys" wherein revegetation has been delayed are deepened by disintegration of bottom soils. During the hot summer the water of these "creveys" becomes overheated, accelerating reduction of organic matter in the soil. Small fragments of peat and plant debris bob up to the surface of the water, made buoyant by clinging bubbles of gas. Large mats of algae and soils from the bottom of the "crevey" are often floated by gas. Floating material drifts to the edges of the "crevey." This process tends to shoal the edges of the incipient pond, while the center becomes deeper.

6-D. *Drought and soil oxidation.* A lake in Vermilion Parish, Louisiana, is said to have been formed as a result of the drying up of a goose "eatout." Though none of the study areas has been subjected to severe drought, plant recovery has been retarded by prolonged dry weather. A long drought such as occurred in this region in 1924 would certainly prevent revegetation and cause the soils of "eatouts" to compact and oxidize so that a pond would result when water levels returned to normal.

6-E. *Soil disintegration in partial "eatout."* Occasionally recovery is delayed in partial "eatouts" by the factors described in 6-C. Cattle and hogs also may trample or uproot recovering food plants, leaving a tufted marsh somewhat similar to niggerhead marsh (4-C).

6-F. *Old "Crevey."* Partial "eatouts" may finally degenerate into mucky ponds with scattered tufts of climax vegetation. Such areas persist for many years and are called "old creveys." When these "creveys" are shallow, culms of tufted climax plants fall and strike root, eventually spreading until climax marsh is produced. When water is too deep for climax plants to spread, the tufts become top-heavy and are washed out of the "crevey," leaving an open pond.

This discussion outlines the many changes known or suspected to occur after goose or muskrat damage to marsh. Unfortunately there is no formula to indicate which of these changes will result from any particular instance of damage, as we can neither foretell nor control factors such as weather and tides that influence recovery. In general the sooner recovery starts in an "eatout," the greater the chance that the marsh will again be productive when reestablished. When repair is delayed 1 to 3 years, unproductive climax marsh may be the eventual outcome. Recovery is very slow in "creveys" that persist longer than 4 years. Complete control of water levels would enable operators to influence the consequences of "eatout," but would entail a large financial investment for levees and pumps, and the results would scarcely warrant the expense. Flumes, tide-gates and spillways offer a degree of water control, and their installation is war-

ranted where marshes are subject to serious drainage.

The amount of marsh completely or partially damaged by geese each year in Louisiana and east Texas varies between 10,000 and 35,000 acres. The goose "eatouts" personally inspected and studied during the past 5 years totaled approximately 40,000 acres, although in some cases the same lands were damaged for 2 successive years. Of this total, perhaps 85 per cent was restored to normal productive marsh by natural processes of repair; climax marsh covered 5 per cent, and because of goose "eatouts" ponds formed on about 10 per cent. Storm washout of an extensive goose "eatout" on the Mississippi Delta and flooding of another in Cameron Parish, Louisiana, damaged by geese for 3 consecutive years, accounted for this comparatively large extent of pond formation.

Many small muskrat "eatouts" of 5 to 100 acres occur every year on the Gulf Coast. More extensive "eatouts" involving thousands of acres are not so infrequent as might be supposed. Six major "eatouts" (the largest involving approximately 10,000 acres) were caused by muskrats during the past 5 years. Muskrat "eatouts" visited and studied totaled about 45,000 acres. Innumerable smaller "eatouts" and one major "eatout" were reported during this study, but were not visited. Three major "eatouts" are reported to have occurred in Louisiana between 1900 and 1935. Identification of the tracts of land on which these "eatouts" occurred has been avoided to prevent embarrassment to landowners and trappers.

Normal productive plant associations have been or are being reestablished on 40 per cent of the total acreage of muskrat "eatouts" studied; worthless climax marsh has developed or threatens to develop on nearly 55 per cent of the damaged marsh; ponds have already formed or will probably form on less than 5 per cent, but because of their trashy nature few of these ponds were productive. A major hurricane might increase the amount of pond formation in both goose and muskrat "eatouts," and probably would increase the value of ponds already formed by flushing out bottom ooze and plant detritus.

SIGNIFICANCE OF MARSH DAMAGE TO MUSKRAT MANAGEMENT

The wintering grounds of blue and snow geese include about 5 per cent of the muskrat marshes of southeastern Louisiana, about 60 per cent of the best trapping lands of Iberia, Vermilion and Cameron Parishes, in southwestern Louisiana, and about 65 per cent of the muskrat marshes of east Texas. Geese often become a problem in muskrat management. They interfere with trapping, temporarily destroy muskrat habitat, and may precipitate "eatouts" on marshes that carry heavy rat populations.

Goose damage is of little consequence to the annual fur harvest of the Gulf Coast, but it often becomes a serious menace to the individual trapper and small landowner. Trappers on the best muskrat marshes suffer most, as their trapping lots are comparatively small. During the winter of 1940–41 study was made of the serious goose damage that affected about 5,000 acres of trapping marsh in Iberia Parish, Louisiana. Individual trapping lots in the best rat marsh here vary between 300 and 500

acres and produce 1,500 to 3,500 rats annually. A flock of 7,500 blue and snow geese settled down on the 300 acres alloted to one trapper, and within 2 weeks totally destroyed 10 acres and partially damaged an additional 60 acres. This trapper estimated that geese caused him to lose 800 rats that season. Other instances of damage were equally serious, and 45 trappers reported some degree of damage to their lands. A 300-acre trapping lot includes open water, bayou banks, and other unproductive marsh. The bulk of the trapper's catch may come from 5 to 15 "pockets" or colonies of rats located on the best portions of his lot. Unfortunately, the greater abundance of food, soft soil, and ample water of the best rat marsh furnish the most attractive feeding ground for geese. Therefore, when geese damage a fifth of a trapper's lot, they may destroy half of his best trapping land.

Geese interfere with trapping in several ways. They spring many traps, putting part of a trapline out of operation. They consume the food needed by muskrats (see Plate 7, A) and destroy the cover necessary to protect young from nocutrnal predators. They roost on rat houses, often causing poorly built houses to collapse. A partially or completely damaged marsh "sours" quickly through decomposition and bacterial action. Muskrats will not tolerate unclean habitats and promptly migrate, deserting 60 out of 80 houses in the week following one severe goose "eatout." Rats usually desert about two-thirds of the houses in a complete "eatout" and less than one-third in partial "eatouts." To catch migrating rats, trappers often set their traps around the periphery of areas being damaged by geese. Extensive goose "eatouts" in heavily populated muskrat marsh may cause over-concentration of rats on land that has escaped damage. This latter marsh may be eaten out by the rats before the goose "eatout" has been sufficiently repaired to be reoccupied by rats. A very extensive muskrat "eatout" in Vermilion Parish was precipitated by goose damage (see Plate 7, B).

Goose "eatouts" usually do not produce such drastic ecological changes as normally follow muskrat "eatouts." As goose damage is less intensive than that caused by muskrats, normal vegetation has a better chance to become reestablished. Several instances of goose damage actually improved muskrat habitat by stimulating food plants and levelling the marsh floor.

When goose damage seriously interferes with trapping operations, its control is warranted. Trappers' activities disturb geese during the trapping season and disperse feeding pressure. After the close of trapping season in February, geese are no longer subject to this disturbance and often inflict serious damage before they migrate in March. Shooting moves geese from small trapping lots, but this control measure can be used only during the hunting season and has other serious limitations. Geese soon learn the range of a shotgun; they fly up when the trapper approaches, only to settle down again when he leaves. Further, the trapper has plenty to carry without adding a shotgun and shells to his load. Rifles cannot be used, both because it is illegal to hunt geese with anything but a shotgun, and because other trappers might be endangered by stray bullets. Flags and scare-

crows fail to prevent goose damage. Firecrackers have produced fair results. Biologist Julian A. Howard of the Fish and Wildlife Service found firecrackers ideal for ducks census in dense marsh. He used a slingshot or "nigger-shooter" to get his firecrackers to explode in the air over feeding birds. The firecracker is fastened to a small stone with a rubber band, placed in the sling, and the fuse touched to the lighted end of a cigarette before release. "Flash-bombs" were effective in controlling damage in east Texas.

Control of goose damage on trapping lots of 1,000 acres or more is difficult. Though damage is usually dispersed on large lots, it invariably involves the best rat land. Careful burning is the most effective control measure. Spring burning would be ideal, but unfortunately it cannot be adopted universally. Some trapping marshes of southwest Louisiana and east Texas can be burned in spring, but vegetation grows so rapidly that were some of the best muskrat marshes burned in February or March, they would have to be burned again the following fall to facilitate trapping. Burning should not be attempted after the middle of March because the nesting season for marsh birds has started by that time. Marsh burned in August usually will have recovered sufficiently by October to be unattractive for geese, but August burning is not to be recommended on outlying marshes that are liable to be swept by storm tides during the fall hurricane season. Spot burning is appropriate for many large trapping lots. This method involves burning off small portions of the trapping lot during the trapping season. The trapper immediately moves his traps into each new burn and with luck will have the rats from that part of his lot before geese have had a chance to damage the land. Spot burning alleviates goose damage and maintains ample escape cover for protection of muskrats during storm tides.

MUSKRAT "EATOUTS"

Muskrat "eatouts" are inimical to marsh management because they result in loss of fur revenues and lower land values. Repair of muskrat "eatouts" may be accomplished in a single year, but a damaged marsh may remain unproductive for decades. Annual revenue from trapping falls off or may cease altogether when "eatout" occurs, and is not fully restored until repair is complete. The monetary loss to trapper and landowner is cumulative during these unproductive years, totaling thousands of dollars on small tracts and hundreds of thousands on large tracts. The sale price of productive muskrat marsh varies between $10 and $35 per acre. There are few data on the sale value of marsh completely destroyed by muskrats, as no experienced fur manager will consider buying it. Often owners of lands adjoining damaged marsh profit from influx of rats, so that one owner profits from another's loss. An influx of rats onto lands already highly populated, however, may lead to dangerous overpopulation, particularly when it occurs in spring and early summer. In such cases the would-be recipient of overflow rats will find his marsh partially or wholly destroyed before he can harvest them the following winter. Much remains to be learned about relation of migration to muskrat diseases. Muskrat migration from "eatouts" usu-

ally takes place, however, when overcrowding predisposes to heavy parasitism, and immigration may bring in diseases. Any benefits from "eatouts" to muskrat management are obscure. Muskrat "eatouts" are a real threat to profitable operation of fur lands. They can be averted only by the most careful supervision of trapping. They can be repaired only by natural revegetation, assisted by light artificial drainage of surface water. "Eatouts" cause tremendous waste of fur resources in animals killed by disease, predators, and fighting. There is grave danger that they will cause a significant proportion of productive marsh to be replaced by worthless climax vegetation.

SIGNIFICANCE TO CATTLE MANAGEMENT

Marsh cattle are an important product of the coastal marshes of southwest Louisiana and east Texas. The firm "high marsh" along the Gulf Coast throughout this region furnishes winter range for these cattle. Though low marsh ridges offer the best supply of forage grasses, these cattle graze into deeper marshes wherever soils are firm enough to support their weight.

Muskrats have not damaged coastal cattle range recently. Older inhabitants recall times when muskrats became so abundant that they over-ran their normal habitat and caused great damage to cattle range and rice crops. Farmers and cattlemen tried to control this damage by breaking open muskrat houses, killing the rats with pitchforks and dogs. The trapping industry is now so well organized that muskrats are confined mainly to the peaty marshes that are too boggy for cattle. When muskrats do become established on the higher cattle marshes, they can be trapped with comparative ease, and periodic droughts force them to leave before they can damage vegetation. Cattle may damage muskrat marshes during dry weather; Lay and O'Neil (1942) recommend fencing to protect some of the east Texas rat marshes from this damage.

Geese can cause severe damage to cattle range. About two-fifths of the wintering grounds of blue and snow geese in Louisiana and east Texas can be classified as cattle range. Cattle graze on the foliage of cordgrass, salt grass, "joint-grass" (*Paspalum distichum*), and three-square, and to a lesser extent on almost all marsh vegetation. As salt marsh vegetation becomes coarse and unpalatable for cattle when allowed to dry and "cure," cattle marshes are burned in late summer or early fall to remove old vegetation and stimulate growth of new grass. Geese are attracted to the tender vegetation in cattle burns, and though they do not graze on foliage much, they uproot forage plants in search of rhizomes. Goose "eatouts" produce little new growth until the following spring and are unsuitable for winter cattle pasture.

The severity of goose damage to cattle range is determined largely by water levels. When water is low, geese may desert high cattle marshes and feed in the deeper muskrat marshes. When normal water levels afford a wider choice of feeding grounds, feeding flocks of geese become smaller and more widely scattered, moving to new marsh before they have completely denuded previous feeding areas. High water, cold weather, or salt water can cause severe

competition between geese and cattle. These factors delay or may destroy plant recovery in burned marsh, causing a shortage of cattle forage. When these same factors, particularly high water, render the deeper marshes uninhabitable, geese concentrate on high cattle marshes, decreasing the already inadequate supply of cattle food. Often goose damage may become so widespread that cattle must be moved to other pastures. This is a hardship for cattlemen lacking reserve pasture. Moving cattle in mid-winter involves considerable expense, including hire of field hands and rental of new pasture.

Marsh cattle have little shelter on winter marsh range and suffer greatly during long spells of cold weather, rains, and northerly winds. Stock must be in the best of condition to survive "wet northers." Underfed cattle often die during bad weather or become so weak that they readily succumb to disease. Surviving animals may be in such poor condition that they lose their calves. Naturally the market value of underfed cattle is low, and many weak animals perish when driven to new pasture or to market. Geese cannot be blamed entirely for damage to stock, but unusual concentrations of geese can greatly aggravate damage resulting from weather and inadequate forage. Goose damage to cattle range contributed to loss of stock in Cameron Parish, Louisiana, during the extremely cold winter of 1939–40, and again in the high water of the winter of 1940–41. Geese devastated approximately 65 per cent of 15,000 acres of cattle range in Vermilion Parish during the winter of 1941-42 (see Plate 7, C), making it necessary to move many cattle. Several hundred cattle had to be moved at Holly Beach, Louisiana, in January 1943, because of progressive destruction of cattle range.

Goose damage to cattle range may be detrimental to cattle management, but it is seldom of lasting consequence; winter goose "eatouts" usually are repaired the following summer. It is immaterial whether secondary or climax plants dominate the vegetation of repaired marsh, as both furnish forage for cattle. Cattle range is permanently lost only when damage results in pond formation.

Goose damage is difficult to control because extensive tracts of land are involved. Riders often patrol areas being damaged and attempt to disperse feeding geese by snapping whips and shooting. Geese soon become accustomed to this and move only a short distance when disturbed. Hazing by airplane would be beneficial when damage became so serious that the expense was justified. Many stockmen burn their winter range in August and early September so new grass will be tall enough to discourage geese arriving in the middle of October.

SIGNIFICANCE TO WILDLIFE MANAGEMENT

Muskrat and goose "eatouts" are immediately beneficial to some forms of wildlife. Species attracted to damaged marsh include shorebirds such as yellowlegs, Wilson's snipe, dowitchers, least, western and semipalmated sandpipers, and black-necked stilts; waders such as herons and egrets, terns including least, black, Forster's, and common; and certain ducks, principally teal, shovellers, gadwalls and baldpates. Spikerush (*Eleocharis parvula*), wigeon-

grass, algae (*Cladophora*), and seeds of marsh plants furnish duck food in "eatouts" in brackish marsh; in the fresh marshes of southesatern Louisiana are wapato, frogbit, and other foods. Crustaceans (*Palaemonetes, Gammarus,* and *Cambarus*), minnows (*Gambusia, Mollienisia, Fundulus,* and *Cyprinodon*), mollusks (*Littorina, Melampus* and *Neritina*), mosquitoes (*Culex, Anopheles* and *Aedes*) and midge (*Chironomidae*) larvae, and other insects including Corixids, abound in new "creveys," furnishing food for ducks, waders, shorebirds, and terns. Mallards, black ducks, and mottled ducks use small openings in the marsh. See Plate 7, D.

"Eatouts" in three-square and "coco" marsh destroy goose habitat. When coco marsh is destroyed by geese or muskrats excellent mallard habitat is lost. "Eatouts" generally are most attractive for wildlife during the first year after damage. Older "creveys" decline in value unless clean ponds develop. Stagnation following "eatouts" predisposes to diseases among wildlife. Knowledge of the diseases and parasites affecting muskrats left in "eatouts" is incomplete. Just before this paper was completed, a mild outbreak of botulism among mottled ducks that had been feeding in a muskrat "eatout" in Vermilion Parish, Louisiana.

As "eatouts" have beneficial and harmful results on wildlife and wildlife habitat, these results should be evaluated from the standpoint of wildlife management. Goose "eatouts" occur during the fall and winter and immediately attract winter ducks. They furnish feeding grounds for migrant shorebirds and bluewinged teal in spring and for mottled ducks and resident waders and shorebirds the following summer. High cattle marshes damaged by geese are much more likely to be taken over by annual duck food plants the following summer than are muskrat "eatouts" in the deeper peaty marshes. Repair of goose "eatouts" is rapid, and usually the marsh is productive when fully restored.

Goose "eatouts," therefore, have a place in wildlife management, but geese should not be encourage to damage lands whereon muskrats and cattle were the principal cash crops. Goose "eatouts" occurring on such lands despite all control measures will provide abundantly for the wildlife thereon.

The problem of goose depredations on wildlife refuges warrants careful consideration and cautious decision. Wildlife preservation and management are primary land uses on the half million acres of Federal, State and private wildlife refuges of this region. Every effort should be made to attract and hold these geese within refuge lands, both to protect these interesting and valuable birds and to mitigate damage they might cause if allowed to concentrate on adjacent fur and cattle lands. Wildlife management is concerned with the preservation of many species other than blue and snow geese, however, and such management requires money. Fur animals are abundant on these refuge lands, and their trapping contributes to control of wildlife predators and furnishes revenues to finance refuge operation. Geese can damage the muskrat marshes of refuge lands and reduce this source of revenue. This damage is a natural consequence of use by geese of lands assigned to them, but it may interfere with our responsibility for man-

agement of other forms of wildlife. This situation does not call for destruction of geese, and no thinking person would advocate such a policy. A practical solution in keeping with sound management would encourage geese to use refuge marshes low in value for other wildlife, and discourage their intensive use of valuable muskrat lands. Marshes intended for geese can be burned at intevals throughout the winter, starting the first of October. Cattle will prolong the value of these burns by closely cropping recovery areas. Geese might be discouraged from using the best muskrat marshes by early burning or spot burning, and by moderate disturbance when there is no danger of driving the birds out of the refuge. Goose "eatouts" on high marsh produce greater wildlife values than those in muskrat marsh, as has been stated. Moderate disturbance, such as is created by movement of trappers on their traplines, and in exceptional cases, by fireworks, is not inimical to the welfare of these birds.

The relation of muskrat "eatouts" to operation of wildlife refuges has long been debated among conservationists. The authors prefer not to become embroiled in this matter, but because some earlier discussion of the issue has been colored by prejudice and misunderstanding, and because the present data are likely to be reviewed critically by representatives of various schools of thought, some clarification seems appropriate. One concept of conservation is the preservation of wildlife and wildlife habitat in the pristine state. Control of a species of wildlife or intentional alteration of wildlife environment would be inappropriate for refuges dedicated to this purpose. As the muskrat is an integral part of the wildlife of the Gulf Coast marshes, it would not be trapped on such inviolate refuges, but rather be allowed to go through its natural cycle of populations despite the effects on the marsh. Neither should regular burning be practiced on such refuges, for this increases the capacity of the marsh for muskrats and other wildlife and vastly alters the biotic picture assumed to have existed in aboriginal times when burning was confined to sporadic natural fires.

Another conservation aim is wildlife management. Management is concerned not only with preservation of wildlife, but also with the increase of selected forms through purposeful manipulation of environment. The investigations and recommendations presented here are identified with management, rather than with preservation of primordial conditions.

Despite their immediate utilization by some forms of wildlife, muskrat "eatouts" offer little to recommend their employment in management of the wildlife refuges of this region. They create temporary habitat for shorebirds and shallow-water ducks, but they destroy habitat of other wildlife. Permanent ponds may be created by muskrats, but it is not recommended that muskrat damage be encouraged for this purpose. A large proportion of the ponds produced on the study areas were relatively unproductive for wildlife. If loss of fur revenues and land values is considered in computing the cost per acre of ponds produced by muskrats, it will be seen that this management method is too costly and inefficient to warrant adoption. It would be cheaper to trap the land regularly and use fur

revenues for hand labor and machinery to dig ponds in the marsh. The authors' recommendation is that muskrat populations on refuges dedicated to wildlife management be maintained at a figure not exceeding the carrying capacity of the marsh. Proper trapping is the only efficient means of controlling muskrat populations and must be recognized as a valid management practice.

SUMMARY

A type of marsh damage, locally known as "eatout," is the normal consequence of the intensive feeding habit peculiar to blue and snow geese. Similar damage results when muskrats are allowed to overpopulate their habitat either through cessation of trapping or improper trapping. This damage disturbs the normal ecology of the marsh; and its consequences may advance efforts at marsh management in some instances but more often menace the profitable operation of the Gulf Coast marshes.

Muskrat "eatouts" have more drastic consequences than goose "eatouts," which are usually repaired quickly by natural revegetation, while the former often produce worthless climax marsh. Goose "eatouts" disrupt muskrat and cattle management programs by interfering with trapping and by destroying cattle forage. Muskrat "eatouts" are inimical to profitable fur management, but have not affected cattle lands recently. Both types of damage benefit certain forms of wildlife, but goose "eatouts" have greater wildlife values and produce fewer harmful results to wildlife habitat. Encouragement of goose "eatouts" within certain limits is, therefore, an appropriate management measure for wildlife refuges. Muskrat "eatouts" should not be encouraged on refuges dedicated to wildlife management in this region.

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MUSKRAT TRAPPING ON SAND LAKE NATIONAL WILDLIFE REFUGE, SOUTH DAKOTA[1]

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There are many ideas as to the best practices for the trapping of muskrats in the north-central United States. Different persons advocate trapping in the autumn, winter, or spring. Trapping within muskrat houses is favored by some persons, while others consider this practice very harmful to the rat population. Some favor setting traps in feeder houses or on feeder platforms, but others do not want sets made within certain distances from houses, feeders, or bank runways.

Inasmuch as trapping technics and the trapper personnel are under control on national wildlife refuges, it seemed desirable to test these various ideas and determine the best practices for managing the muskrat harvest on these refuges.

The Sand Lake National Wildlife Refuge in northeastern South Dakota near Aberdeen was chosen as well suited for the study, as it is located in an area typical of northern rigorous winters. This Refuge includes about 11,000 acres of open water and marsh, and in the autumn of 1943 had a population of about 12,000 muskrats. The Refuge extends from four miles south of the North Dakota line on the James River southwesterly along the river bottom for 16 miles. The width varies from one to three miles; about half of the area is composed of open water and marsh. The water levels are controlled by two dams, the lower or Columbia Dam backing up water eight miles to the Mud Lake Dam. The latter in turn impounds the water to the Hecla grade. Above this point for one mile the water is restricted to the river channel and two small bays.

The area was first flooded in the summer of 1941 and provided the first good crop of muskrats; a share cropping system was inaugurated, and 2,663 animals were harvested. Previous, trapping had been by the Refuge personnel. During the 1942–43 season, 8,000 were taken, in 1943–44, 8,069, and in 1944–45, 4,104 were removed. Data for this paper are from the latter two seasons.

The study included a comparison of autumn, winter, and spring trapping of muskrats to determine the amount of effort required to catch muskrats under these seasonal conditions, and the size and primeness of the furs obtained. House trapping was practical only during the winter; this was given detailed study to determine the ill effects, if any, this would have on the muskrats. During the second season, the study dealt with movements of the animals, weights, and sex ratios, and further attention was given to house trapping.

A type map was made of the emergent vegetation on the whole refuge to

[1] Members of the Division of Wildlife Refuges cooperated in this investigation; mangers, Robley W. Hunt and Jerome H. Stoudt successive residents and their staffs attended to many field details; and Charles E. Kellogg and Laurits W. Krefting assisted in organization and execution of the study.

provide better understanding and interpretation of the data. Submergent vegetation is scarce and was not considered. Coincident with the type mapping, a count was made of all muskrat houses.

TABLE 1.—MUSKRAT CATCH IN RELATION TO NUMBER OF HOUSES AND ACRES OF GOOD FOOD PLANTS.

Unit number	Muskrats trapped	Houses	Average rats taken per house	Acres good food	Rats taken per acre good food	Houses per acre good food	Per cent houses in good food types	Average length of April skins, inches
1	1,000	217	4.61	129	7.65	1.68	*97*	15.8
2	382	128	2.98	303	1.26	.42	*100*	16.0
3–4[1]	1,073	242	4.44	179	6.00	1.35	*76*	16.1
5	217	126	1.72	84	2.58	1.50	*79*	—
6	652	215	3.30	131	4.96	1.64	*73*	16.8
7	1,337	460	2.91	252	5.23	1.82	*82*	17.6
8	1,203	291	4.12	135	8.92	2.16	*49*	17.8
9	637	316	2.01	478	1.33	.66	*91*	—
10	934	484	1.94	524	1.78	.61	*79*	17.7
11	272	197	1.38	149	1.82	1.32	*93*	17.4
12	362	147	2.46	156	2.32	.94	*95*	16.6
Totals or averages	8,069	2,823	2.86	2,520	3.20	1.13	*81*	—

[1] Combined due to lack of proper boundary divisions.

FOOD TYPES AND MUSKRAT ABUNDANCE

The dominant marsh vegetation is restricted to a few species which include river bulrush (*Scirpus pluviatilis*), reed (*Phragmites communis*), cord grass (*Spartina gracilis*?), sprangle top (*Leptochloa fascicularis*?), and smart weed (*Polygonum*). Of minor importance are small patches of round stem bulrush (*Scirpus acutus*) and cattail (*Typha latifolia*).

The count of houses showed that 81 per cent were located in bulrush, reed, or mixed types containing considerable quantities of these two species (Table 1). The remainder were in the sprangle top, cord grass, and smartweed types. The types containing good food (reed and bulrush) covered approximately 23 per cent of the marsh, the poor food types (smartweed, sprangle top, and cord grass) 9 per cent, and open water 68 per cent. The muskrat houses disintegrate each spring when high water from the spring run-off passes through. This makes it necessary for the muskrats to construct new houses each year and as a result the house count each winter is a direct index of muskrat abundance on the area.

FALL TRAPPING

In 1943, fall trapping started on November 10, but due to bad weather conditions, poor results were obtained. A snowstorm November 5, followed by a cold wind and drifting snow formed a 2-inch coating of ice and snow. This condition made bank trapping almost impossible as the runways could not be located. Part of this difficulty could have been eliminated had runways been

marked some time during October. This 2-inch coating of ice made boat travel impossible, but was still not safe for foot travel. The trapper tried making under-water sets but on one occasion fell through the ice. On November 18 two more trappers were assigned to the project in order to get a better representation of fall trapping. These men were better trappers, but even they had difficulty in making sets. All trapping ceased on December 31, the end of the fall period. By this time, the ice had attained a thickness of 12 inches.

TABLE 2.—WEEKLY ICE DEPTH READINGS ON SAND LAKE.

Date	Ice depth inches
December 8, 1944	5
December 16, 1944	6
December 23, 1944	13¼
December 30, 1944	16
January 6, 1945	18½
January 13, 1945	19½
January 20, 1945	19½
January 27, 1945	22½
February 3, 1945	26½
February 10, 1945	30
February 17, 1945	33

Ice depth during the trapping season of 1944–45 showed that by the middle of December trapping through the ice would have been very difficult (Table 2).

Due to the above-mentioned difficulties, only 321 muskrats were taken from the fall trapping unit. These 'rats were taken from the following locations: near houses (water sets) 30, in small feeder houses 218, bank runways 72, and 1 killed on the ice. The first man assigned to this unit was a poor trapper and the data obtained from his efforts are not truly representative. His time records show that he took 1.2 hours on the marsh for every muskrat trapped; the average for the other two trappers was .5 of an hour. These figures, when compared with those obtained from winter house trapping (.34 hours per 'rat) show a low trapping return for the fall period.

An examination of weather records (Aberdeen, South Dakota) back through 1934 shows that on an average difficult fall trapping will be encountered after November 20 (Table 3). An analysis of pelt size by semi-monthly periods shows that the skins taken between November 10 and 15 varied from 11 to 17 inches in length and averaged 14.5 inches.[2] Primeness analysis showed that 11.1 per cent were unprime, 50 per cent one-fourth prime, 11.1 per cent one half prime, 16.7 per cent three-fourths prime, and 11.1 per cent completely prime. The latter group, however, were all "paper" skins. Primeness is here based on the degree of blueness of the skins. During the second half of November, the size increased slightly so that the average was 14.6 inches and 5.8 per cent were unprime, 40.4 per cent one-fourth prime, 28.8 per cent on-half prime, and 25 per cent three-fourths prime. This shows a distinct improvement in prime condition. By the second half of December a few skins had attained a 20-inch length and 3.3 per cent were unprime. 20.3 per cent one-fourth prime, 38 per cent one-half prime, 32.2 per cent three-fourths prime, and 6.2 per cent had become fully prime (Figures 1 and 2, and Table 4).

A comparison of these fall trapped skins with those taken later in the sea-

[2] Length refers to greatest over-all length or that distance between tip of nose and base of tail.

TABLE 3.—TEMPERATURE RECORDS FROM ABERDEEN, SOUTH DAKOTA, FOR THE MONTH OF NOVEMBER. THE BOLDFACE TEMPERATURES INDICATE THE PROBABLE DATE AFTER WHICH EFFECTIVE FALL TRAPPING WOULD BE DIFFICULT.

Day	1944		1943		1942		1941		1940		1939		1938		1937		1935		1934	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	65	30	31	29	43	25	53	20	58	31	33	21	66	38	47	34	***27***	***−3***	42	18
2	54	34	36	28	36	26	53	25	56	29	37	22	48	37	40	20	18	9	41	33
3	36	19	46	17	42	22	58	23	56	35	47	16	45	31	55	7	22	14	56	32
4	33	17	46	30	55	42	34	31	40	32	45	26	58	17	60	24	28	2	58	32
5	42	30	36	26	53	29	32	25	33	28	57	15	48	26	60	20	24	4	71	29
6	45	37	30	27	32	23	30	22	40	25	60	21	***36***	***11***	68	18	45	10	60	40
7	52	38	28	26	39	22	32	19	40	20	47	28	35	4	54	36	40	35	51	38
8	39	35	***32***	***14***	43	21	32	27	55	34	47	15	55	4	53	29	46	26	45	27
9	39	32	32	9	48	40	33	25	34	24	50	32	50	28	58	30	38	24	56	32
10	36	28	36	26	41	14	39	27	***26***	***11***	34	15	40	22	60	28	24	14	46	28
11	45	33	49	17	46	25	52	26	10	0	53	16	39	28	68	40	30	2	48	20
12	42	36	36	27	54	34	62	29	9	−5	58	14	37	27	54	45	39	19	60	24
13	54	38	32	17	57	22	45	25	9	−9	68	20	27	13	45	30	20	15	47	30
14	50	33	36	16	43	29	54	25	10	−13	61	22	32	2	34	26	15	13	57	27
15	40	28	20	12	67	29	60	39	34	0	67	20	31	11	26	20	20	1	62	26
16	36	25	48	11	67	29	58	34	49	26	65	18	49	16	***22***	***11***	41	20	67	32
17	43	27	53	26	53	21	40	33	47	20	57	16	49	20	22	4	38	24	40	29
18	38	22	54	27	43	19	40	32	49	32	52	18	48	9	20	11	36	32	40	25
19	36	25	46	12	48	35	35	26	37	22	53	17	56	30	18	10	32	11	45	39
20	31	24	48	23	36	24	28	15	40	17	45	14	44	16	10	−8	31	16	39	38
21	32	22	30	11	35	22	40	16	35	29	56	14	26	8	11	−12	18	8	39	−
22	38	28	30	16	***29***	***11***	***22***	***5***	30	25	61	18	25	−10	31	5	28	−1	26	14
23	51	27	47	17	43	20	32	4	39	22	48	35	18	−2	40	26	38	22	46	24
24	46	31	37	30	52	30	44	12	38	15	40	29	28	−12	41	29	42	20	40	25
25	42	27	36	30	52	22	52	26	39	22	35	27	31	8	45	29	38	20	36	32
26	***27***	***19***	30	15	24	8	59	25	29	21	44	21	15	−5	43	21	43	18	34	28
27	27	16	28	17	29	9	48	21	21	8	46	21	34	−10	21	7	28	27	33	24
28	25	16	36	20	21	10	46	16	24	3	49	28	49	10	17	−2	28	8	***54***	***15***
29	21	12	45	26	22	9	34	15	20	2	***48***	***11***	43	19	23	−6	44	16	36	18
30	14	−1	41	23	22	4	32	14	18	9	58	19	40	21	27	5	42	34	30	14
Mean	39.3	26.3	38.7	23.8	42.8	22.7	45.6	22.7	34.2	17.2	50.7	20.3	40.1	13.9	39.1	17.9	32.1	15.3	45.	27.3
Departure from avg.	+2.3		+0.6		+2.2		+2.0		−4.9		+4.9		−3.6		−2.1		−6.8		+6.1	

Note—Records for 1936 were not available when report was prepared.

son shows that the value of the skins due to small size and unprime condition is enough lower than later skins to justify delaying trapping until they attain a more nearly maximum value.

and predation. Whenever possible some of the wet material from within the house was used for part of the plug as this froze in place making the seal almost perfect.

TABLE 4.—PERCENTAGE DISTRIBUTION OF SKIN SIZE CLASSIFICATION BY SEMI-MONTHLY PERIODS FOR 1943–44.

Skin length	November		December		January		February		March		April
	1–15	16–30	1–15	16–31	1–15	16–31	1–15	16–29	1–15	16–31	1–15
11	5.6	1.9		.3							
12	5.6	3.8	.9	.8	.1						.1
13	5.6	25.0	5.4	1.8	.7	.5					.3
14	33.3	19.2	20.5	8.3	4.2	1.9	.3	.5	.5	.9	2.7
15	16.6	15.4	31.8	22.1	12.7	7.4	5.6	6.1	2.2	1.2	10.9
16	27.7	21.2	26.4	30.2	26.5	25.5	16.4	18.4	8.2	6.6	18.9
17	5.6	13.5	10.0	23.5	29.9	33.1	32.4	56.7	23.2	22.5	27.8
18			4.1	11.2	21.4	25.4	34.1	14.8	50.8	44.5	30.2
19			.9	1.5	3.9	5.3	9.2	3.0	14.4	15.0	7.7
20				.3	.5	.7	2.0	.5	.7	7.5	1.3
21					.1	.1				1.8	
22						.1					.1
Basis	18	52	557	1,320	1,735	1,231	305	196	415	333	1,422
Av. skin length*	14.5	14.6	15.2	16.0	16.6	16.9	17.3	17.9	17.7	17.9	17.0

* Length refers to greatest over-all length or that distance between tip of nose and base of tail.

WINTER TRAPPING

Winter house trapping started on December 1 and continued through March 31. Ten units were trapped during this period. Openings in the houses were made with either narrow bladed spades or wedge-shaped bars similar to an ice chisel. These holes were usually about 6 inches in diameter or just large enough to permit entry of the arm while setting the traps. If weather conditions and the house construction permitted, the openings were usually made on the south side of the houses. The holes were carefully plugged while traps were in the houses and just as carefully plugged when they were removed. This was a necessary insurance against freezing

The muskrat house walls are so solidly frozen in this section from about December 15 until March 1 that a sharp chisel-like tool is necessary for making a proper opening. An axe is very unsatisfactory because it is impossible to make a clean-cut hole through thick-walled houses. This frozen condition of the walls makes house trapping much more satisfactory than in areas where they remain unfrozen. Animals caught in these houses do not tear down the structures in their struggles except in thin-walled "push-ups."

The trappers employed about 25 to 30 traps each; usually setting their traps in the morning and visiting them about three times before evening. The

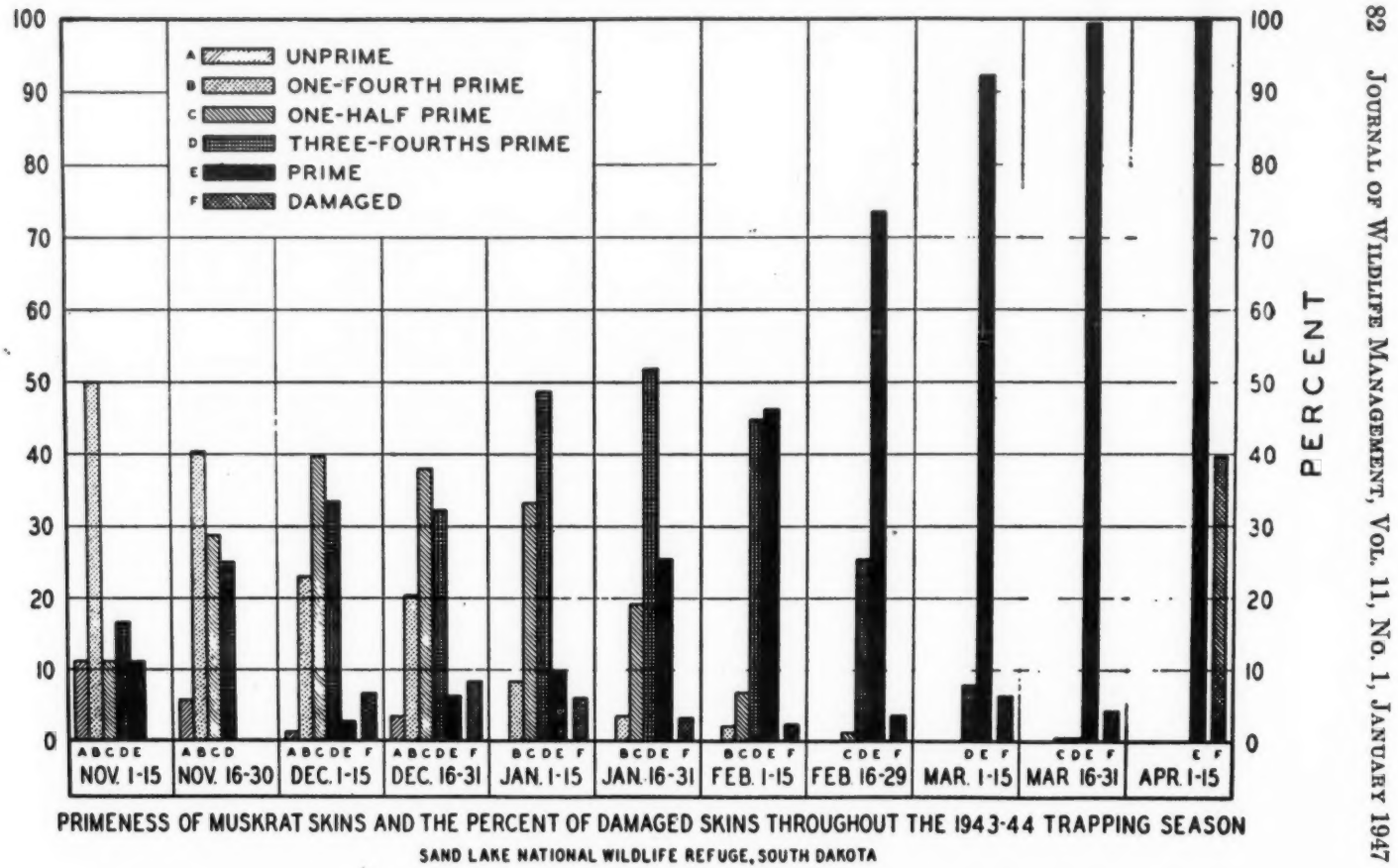

FIG. 1. Primeness of muskrat skins and the percent of damaged skins throughout the 1943–44 trapping season, Sand Lake National Wildlife Refuge, South Dakota.

traps were then left set in the houses over night and visited at regular intervals the following day. When a house failed to produce a catch during the daily visits, and again the following morning, the trap was removed from the house. As soon as about three-fourths of the houses failed to produce muskrats, the traps from the other one-fourth were removed and set in another group of houses. This trapping pressure may seem a little severe, but it is believed that sufficient breeding stock was left in houses obscured by drifting snow, in bank dens, and houses not trapped dry, to maintain the population if other factors were favorable. In this way the traps were kept relatively close together and could be visited more frequently. This procedure made it possible to get most of the animals alive which saved time in skinning and preparing the pelts. The use of stop-loss traps practically eliminated leg chewing and "wring-offs" thus avoiding considerable suffering and loss of animals.

During the winter period a total of 7,476 muskrats were taken by house trapping. Time spent on the marsh by four of the trappers, during which time they took 4,383 'rats, showed that they averaged .34 of an hour per animal. Length of skins gradually increased up to the forepart of February, when they averaged 17.9 inches (Figure 1; Table 4). During the next two semi-monthly periods they remained about constant. The primeness analysis showed a very distinct increase in the amount of clear skin. By the first of January there were no longer any entirely unprime skins and those one-fourth and one-half prime were declining in numbers. The three-fourths and fully prime skins were in the majority, and by the latter half of March, 99.4 per cent of them were prime (Figure 2). These size and primeness analyses show conclusively that skins taken after the middle of January are more valuable than those taken earlier.

Of interest is the abrupt appearance of damaged skins during December and

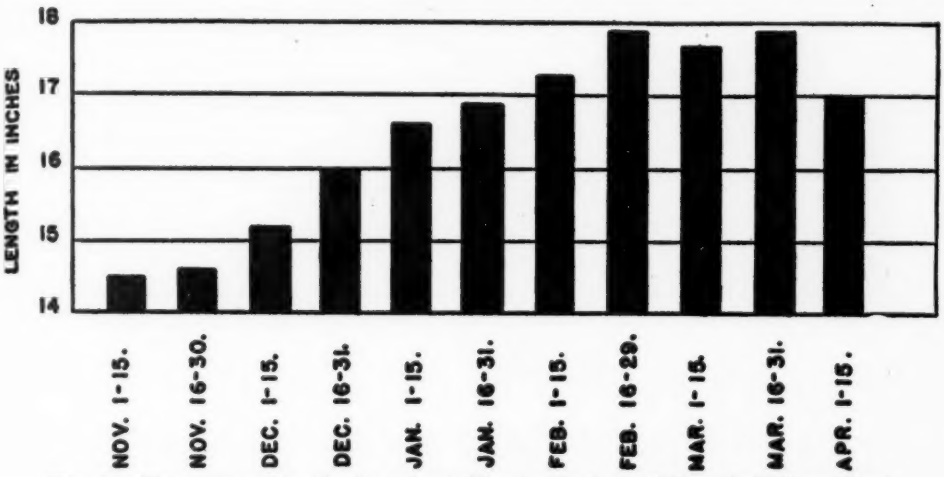

FIG. 2.—The average length of muskrat skins by semi-monthly periods throughout the 1943–1944 trapping season at Sand Lake Refuge.

Sand Lake National Wildlife Refuge, South Dakota.

January and then a decline until late in March. This may be due to fighting during migration from shallow water areas to more suitable sites. Evidence of this will be discussed more fully under the house trapping studies.

SPRING TRAPPING

Spring trapping started on April 1 and continued for fifteen days, during which time no house trapping was permitted. Bank runway sets were permissible but the greatest number of muskrats was trapped on floating board sets. The efficiency of this type of trapping was very high, as the trappers required only an average of .18 of an hour on the marsh for each animal taken. The skins were 100 per cent prime but slightly smaller (17.0 in.) than the late winter rats. This smaller size may be a reflection of habitat influence as most of them were taken along banks and dams. The incidence of "paper" skins was the highest of any semi-monthly period.

Fighting among the animals was common as nearly 40 per cent of the skins were damaged. The trappers found a much higher percentage of the live 'rats damaged than those which had drowned. Apparently a live muskrat in a trap during the mating season is a fighting invitation to other antagonistic animals. Both the trappers and the Refuge personnel believe that the great majority of damaged skins are caused by other muskrats, rather than by predators. The nature of the damage to the skins substantiates this hypothesis. If spring trapping is undertaken all precautions possible should be taken to make sets that will cause the quick drowning of muskrats so as to reduce these losses. The high incidence of damaged skins and the short season during which spring trapping can be done are both important factors if spring trapping is considered.

HOUSE TRAPPING

The data previously related were gathered incidental to fall, winter, and spring trapping. In addition to these analyses, studies were made on various techniques and their effects on house trapping.

RELATION OF WATER DEPTH TO SIZE OF HOUSES

A total of 350 houses on all study plots were marked and the water depth, size, and construction recorded. These houses were found in water varying from 6 to 35 inches and are believed to be representative of the whole marsh. In general there was no relation between house size and depth of water. The size of the house was governed by the kind and amount of food and the number of animals using it. There were no large houses in water less than 10 inches deep, but at that depth and deeper all sizes were found. The large houses formed 21.8 per cent, medium 34.5 per cent, and small 43.7 per cent of the total; 20.7 per cent of the houses were in water 25 inches or deeper, 39.9 per cent in water 16-24 inches, and 39.1 per cent in water 16 inches and less. A depth of about three feet is the maximum in which houses will be built and the optimum depth is somewhere between 16 and 30 inches. Small houses were defined as those 15–18 inches high and 24–36 inches wide, medium 18–24 inches high and 36–48 inches wide, and large ones all those larger than mediums.

FACTORS INFLUENCING THE "FREEZING-OUT" OF MUSKRAT HOUSES

Muskrat houses often freeze up during the winter even when they are protected from trapping. One of our trapping studies was designed to determine those causes other than cold weather. Early in January, 1944, 183 untrapped houses were opened to determine whether they were frozen or active. The water depths were recorded alongside of each house. Part of this series, opened during the forepart of January, showed that 67.7 per cent of those houses in water up to 15 inches deep were already frozen up inside. Those in water 16 to 25 inches deep had 40.3 per cent frozen and those in water deeper than 25 inches had only 12.9 per cent frozen. Another group of houses, left untouched until early in March, showed that those in water 15 inches or less were all frozen; those in water 16 to 24 inches were 86 per cent frozen and those deeper than 25 inches were 22 per cent frozen (Table 2). This is a normal condition that may occur in the marsh any winter as trapping disturbance was not a factor.

Another group of 65 houses were opened and closed to create a disturbance with no traps being set. When these houses were first opened on January 12, 41 per cent of them were already frozen up and 59 per cent active. On January 12 the minimum temperature was −9° and on the 13th, 3°, yet there was no change in ratio of active and frozen houses. They were again opened on January 18, and the ratio was still the same. The active houses were largely in good food habitat and deep water and an analysis showed that it was those in the bulrush or reed and in the deeper water that remained active. It is apparent that the activity of the muskrats is the main factor that keeps the houses from freezing and in order to be active the animals must have access to an ample food supply.

To supplement the above experiment another 35 houses were opened and left unplugged. On January 14, when the minimum temperature was 10°, 21 houses were thus opened. The next day 20 were found plugged and active and 1 was frozen and deserted. All the houses were again left open. On January 17 they were again examined and 19 were plugged and active and 2 frozen. One of the frozen ones had a second chamber which was active. The minimum temperature on January 17 was 8°. On this date 14 more houses were opened and left unplugged. The next day 11 were plugged and active, 3 were unplugged but not frozen. On this same date the 21 houses were again opened and examined 45 minutes later. At that time 3 were completely plugged, 9 were partially plugged, and 9 were open and showing no signs of activity. The next check of these 35 houses was on February 6, when 30 were found to be plugged and active, 2 frozen, and 3 lost in drifted snow. The night of February 6 the temperature dropped to −9° and the next day they were all reexamined. There were then 29 plugged and active, 3 frozen, and 3 lost. On Fegruary 13 after minimum temperatures of 12°, 16°, −8°, −6°, −22°, and −31°, they were again opened. There were then 31 plugged and active and 1 frozen. That night the temperature was −4° and the next day 28 were plugged and active and 4 frozen. The final check of these houses was made on March 3 when 28 were plugged and active, 5 frozen and 2 lost.

These experiments indicate that muskrats desert a large percentage of the shallow water houses sometime before January 15. Whether this is caused by thickening ice restricting their activity, or the lack of proper food, is not known; it is more than likely a combination of these factors. Desertion and subsequent lack of activity allows the plunge hole to freeze over, and a normal healthy muskrat with ample water and food will not permit this to occur.

Further evidence that the animals desert shallow water areas is born out by the rise in the quantity of damaged pelts during late December and early January (Figure 2), caused by fighting when strange muskrats invade the homes of others. In one unit about 50 per cent of the houses were in shallow water where the dominant vegetation was sprangle top. In this area 69.3 per cent of the houses were frozen in March, 1944, and as a result no muskrats were trapped. Most of the active houses (30.7 per cent) were at the edge of the sprangle top and along the river channel. In this same unit the following year, 1944–45, shallow water houses were trapped during December. At that time nearly all houses were active, and 102 of them produced 275 animals.

These studies led to the question "What influence does the trap have in houses carelessly left open by trappers?" To obtain information on this subject traps were set in 29 houses and the opening left unplugged. This was done on January 15, 1945, and on that day only 5 muskrats were caught although the traps were visited twice. During the next two days these traps were visited 3 times daily and 44 animals were removed from the houses. By that time 6 of the houses had frozen up inside and the traps were removed. The remaining 23 houses were then carefully plugged with the traps set in them. In 3 more days 15 additional muskrats were taken, which made a total catch of 59 animals from 29 houses. At the end of this period 5 of the houses were still active.

While the open hole trapping was being done, another series of 31 houses in a comparable habitat were being trapped in the regular manner. At the end of 3 days a total of 84 animals were removed from the closed hole series and 6 houses were still active.

These two series indicate that the setting of traps in open houses restricts activity of the animals bringing about a smaller return than from traps set in closed houses. The closed house method produced 2.7 and the open hole set 1.5 'rats per house. This certainly demonstrates that the efficiency of house trapping properly done is much greater than when practiced improperly.

SEX AND WEIGHTS DATA

Between January 13 and 31, 1945, a total of 237 animals trapped during that period were sexed, weighed, and measured. Another 83 were weighed and measured but not sexed. The sex ratio of these animals was 64.2 per cent males and 35.8 per cent females. The males average 33.8 ounces each and the females 32.6 ounces. The average total length and tail length of the males was 20.6 and 9.1 inches and of the females 20.5 and 9.1 inches.

There was little difference in average weights and measurements of animals taken from the different units, but had the data been segregated by habitats,

it is believed some significant differences might have been found. During this January period the largest male was 50 ounces and the largest female 43 ounces; the smallest male 17 and the smallest female 22 ounces.

SIZE OF MUSKRATS IN RELATION TO HABITAT

Units were not all trapped simultaneously so it was impossible to make direct comparisons between all units. However, during April, muskrats were taken from 10 of the units and the measurements of the skins indicate that the larger rats are produced in those areas harboring the greatest concentrations of bulrush and reed. The size was slightly smaller in those areas where a large number of bank rats are normally present.

THE 1944–45 TRAPPING SEASON

During the 1944–45 trapping season 4,103 muskrats were harvested. This is roughly half the catch of the previous two seasons when 8,000 and 8.069 were taken. There may have been one or several causes of this decline. The animals may have been in a period of cyclic decimation, trapping pressure may have been too severe, or the habitat may have changed. So little is known about the muskrat cycle that the mention of it as a possible cause is sufficient. Excessive trapping pressure could have been a contributing factor, but it is not felt that it alone was responsible, as the same pressure (8,000 muskrats) in 1942–43 did not reduce the catch for 1943–44 when 8,069 were taken. Habitat changes may have contributed more to the decline than overtrapping. Although no survey of food types was made in 1944–45, we do know that there was a reduction in the acreages of bulrush in many areas. One bulrush area of 1¼ acres had 19 houses on it in 1943–44 and in 1944–45 there was none.

It is interesting to note that the reduction in houses in 1944–45 was almost proportional to the number of animals taken, the number of muskrats caught per house remaing about the same (Table 5). Thus it would appear that a winter house count is a pretty good measure for setting the season's catch quota; at least it is applicable to areas where the houses disintegrate each spring.

Whether the preponderance of males (64.2 per cent for January, 53 per cent adult for summer, and 60.7 per cent immature in summer) was a cause or a result of the muskrat decline is not known, but it may have some significance. Unfortunately sex analysis was not made of the first winter's catch. Cases where males predominate (Marshall 1937, Hatfield, 1939, Errington 1940, Buss 1941, and Dosier and Allen 1942), are common, but may reflect a condition of selective trapping or some other factor not truly representative of sexual sampling. This might well be the case with the summer live trapping of adults but immature animals should be less influenced by habits associated with sex. The winter catch, which was taken entirely from houses that were heavily trapped, should have shown a fairly true index of sex ratios.

MOVEMENTS OF MUSKRATS

In the summer of 1944 the writer live-trapped and ear tagged 367 muskrats

for the purpose of determining the movements of the animals. The data on the technic were published (Aldous 1946) before the season's trapping returns were tabulated. The number tagged included 164 adults and 196 immature. Five animals were not classified as to age class. For age separation those 2 pounds or over on the first capture were classified as adults and those under that figure as immatures. While this age criterion is not accurate it was felt that for the late summer and early fall period, it was a relatively satisfactory maturity division.

During the winter trapping period, 85 of the tagged animals were recaught by the trappers. The ratio of mature and immature animals when tagged (54.2 per cent immature) was about the same among the 85 recaught during the winter period (51.8 per cent). This would indicate that the survival among adults and immature was about the same.

On the basis of 171 recaptures of tagged animals, a certain amount of information was obtained on their movements. One hundred sixteen were recaptured once, 36 two times, 14 three times and 5 four times.

Practically all of the first litters were raised in bank dens, as all winter houses were destroyed by spring floods. This made it necessary to start live trapping operations on the banks, moving to house colonies as they appeared in the marsh. This movement into the marsh accounted for some of the travels recorded by individual animals.

The movement of these marked animals were recorded by 10-rod intervals (Table 6).

The returns show that there is a tendency for muskrats to remain quite

TABLE 5.—MUSKRAT CATCHES AND HOUSE COUNTS FOR TWO SEASONS—1943–44 AND 1944–45.

Unit No.	1943–44			1944–45			Catch	Houses
	Catch	No. houses	Catch per house	Catch	No. houses	Catch per house	Gain or loss in 1944–45 over 1943–44	Gain or loss in 1944–45 over 1943–44
							Per cent	*Per cent*
1	1,000	217	4.61	212	86	2.46	*− 77.8*	*− 60.4*
2	382	128	2.98	71	25	2.84	*− 81.4*	*− 80.3*
3	1,073	242	4.44	230	78	2.95	*− 69.9*	*+ 37.0*
4				93	156			
5	217	126	1.72	0	0		*−100.0*	*−100.0*
6	652	215	3.30	285	132	2.16	*− 56.3*	*− 38.6*
7	1,337	460	2.91	558	168	3.32	*− 58.3*	*− 63.5*
8	1,203	291	4.12	681	222	3.06	*− 43.5*	*− 23.6*
9	637	316	2.01	412	170	2.42	*− 35.4*	*− 46.3*
10	934	484	1.94	683	190	3.59	*− 26.8*	*− 60.7*
11	272	197	1.38	418	172	2.43	*+ 53.7*	*− 12.7*
12	362	147	2.46	458	196	2.34	*+ 26.5*	*+ 33.2*
Totals	8,069	2,823	2.9	4,101	1,595	2.6		

Reduction in 1944–45 equals *49.2%* in catch and *43.6%* in number of houses.

TABLE 6.—MUSKRAT MOVEMENTS AS DETERMINED BY RECAPTURES OF TAGGED ANIMALS.

Travel distance	Number of cases
Recaught at same station	136
1 to 10 rods	38
11 to 20 rods	23
21 to 30 rods	15
31 to 40 rods	7
41 to 50 rods	9
71 to 80 rods	9
91 to 100 rods	6
151 to 160 rods	6
191 to 200 rods	1

close to their home territory, as 54.4 per cent of the recatches were at the same station where last released. Fifteen and two-tenths per cent moved a distance under 10 rods which is within the limits of the daily feeding radius. It can then be interpreted that 69.¼ per cent of the recatch records indicate no migratory movements. Nine and two-tenths per cent moved between 11 and 20 rods and 6 per cent between 21 and 30 rods. That leaves only 15.2 per cent that travelled in excess of 31 rods. The greatest migration was 200 rods or .62 miles performed by one animal. Two of the half-mile travels were made by one muskrat which was caught that distance from the point of original release and retaken the next day at the place of the first capture.

SEXES AND WEIGHTS

During the live trapping operations, most of the animals were sexed and weighed before being released. The smallest animals taken weighed only 4 ounces and the largest 3 pounds. The growth rates of young animals as shown by subsequent recaptures is quite variable. The growth rates on 6 of these animals is shown in Table 7.

It is interesting to note that the growth rates on all these young was below the average found by Errington (1939). In fact they more nearly approach his minimum figures. The variance in growth rates between these young and those in Iowa, as well as the variation in growth between individuals, could well be explained by the extremely small sample.

The sex ratio of the tagged animals was 53 per cent males and 47 per cent females for the adults, and 60.7 males and 39.3 per cent females for the immature animals. This high male ratio among young muskrats is higher than Errington's (1939) figures but both show a preponderance of males among immature animals.

TABLE 7.—GROWTH RATES ON YOUNG MUSKRATS AS SHOWN BY THE RECOVERY OF TAGGED SPECIMENS.

Tag No.	Sex	Weight on first capture	No. times recaught	Weight on final capture	Time interval	Distance travelled
		Ounces		*Ounces*	*Days*	*Rods*
187	M	8	1	21	102	10
263	M	4	2	23	94	18
276	M	6	1	21	91	50
299	M	8	3	21	99	30
324	M	6	1	25	96	50
343	M	12	1	25	96	40

SUMMARY

Fall trapping is inferior to winter house trapping and spring trapping for the following reasons: (1) weather conditions are so variable that it is often difficult to get the job done within the specified time limits; (2) the trapping success is lower than by methods used in winter and spring; (3) the fall skins average smaller and are largely in a low degree of primeness, both of which reduce their value.

Winter house trapping if properly done is an efficient method of harvesting muskrats. Shallow water areas should be trapped between December 15 and January 15. This would remove most of the animals from these areas before they are forced out and would prevent some damaged skins. Opening and closing houses during the winter is not detrimental if done properly and the house is in a good habitat. Muskrat activity is essential if the plunge hole is to be kept open during extremely cold weather. If a house is "trapped out" or is deserted, nothing will prevent it from freezing during cold spells.

Furs taken during the winter period demand a good price because they have reached a maximum size by February and the primeness increases until the end of February. During January, February, and March, the majority of the furs are three-fourths and fully prime.

Spring trapping is the most efficient method of harvesting the muskrats but by the time this is possible the animals are breeding and a large percentage of the furs are damaged from fighting. The value of the skins is high due to maximum size and complete primeness but the damaged ones lower the average price materially.

The sex ratio of animals trapped from houses during January was 64.2 per cent males and 35.8 per cent females. During the late summer live trapped animals averaged 53 per cent adult males and 47 per cent adult females. Immature animals averaged 60.7 per cent males and 39.3 per cent females.

Based on 250 recaptures of tagged animals, 54.4 per cent showed no movement from place last released, 15.2 per cent moved 1 to 10 rods, 9.2 per cent 11 to 20 rods, 6 per cent 21 to 30 rods. Only 15.2 per cent moved more than 31 rods. The maximum distance recorded was 200 rods.

Growth rates on small animals was someshat less than that recorded for Iowa muskrats.

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BUCCAL FOOD IMPACTION IN WHITETAILED DEER AND *ACTINOMYCES NECROPHORUS* IN BIG GAME[1]

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The entire head of a male whitetailed deer (*Odocoileus virginianus*), about 2½ years old, shot during the hunting season, was sent to the wildlife disease laboratory by Mr. B. Q. Langdahl, Game Warden at Carlton, Minnesota, on December 12, 1945. He stated in a letter that, "The animal was in very poor condition. Several other reports of deer in similar condition have come to my attention. The deer were all taken in this area."

Upon examination the head showed a firm, movable mass on the right jaw, and the skin over the enlargement was largely denuded of hair (Pl. 8, A). An attempt to remove the skin over the affected area disclosed a large impacted food mass in the right buccal cavity, over which the skin and musculature of the cheek were stretched to parchment thinness. The mass (Pl. 8, B) measured 10×15×7½ cm. and weighed 21 ounces. The first two right upper molars were loose and displaced mesally, but the lower molars appeared unaffected. The gum was receded on both the upper and lower right lateral tooth lines, the upper gum farther than the lower.

The origin of this condition is uncertain. It may have started with plant barbs, or awns piercing and irritating the gums with resultant pain in chewing. The pain could have resulted in limited jaw motion, with little or no rotating motion of the lower jaw. Ordinarily this rotation keeps the food moving from the space between the cheek and teeth into the mouth. With suppression of rotary chewing, food could accumulate in the cheek pouch, to pack and become a large mass.

The pressure of the food mass resulted in shrinking of the gums, and subsequent inflammation of the tooth sockets. Such a condition could eventually bring about death of the animal from emaciation and complications, or general infection originating in the infected teeth.

A review of published reports on similar conditions in wildlife indicates wide geographic distribution of *Actinomyces necrophorus*, which is usually associated with this difficulty. The diseased condition resulting from invasion of the tissues of the mouth, tongue, head, throat, stomach and liver by this organism is properly known as necrobacillosis. (The term necrotic stomatitis is used frequently when referring to cases where the head and oral tissues are principally affected.)

The earliest report was of an extensive study of necrobacillosis in the elk herd at Jackson Hole, Wyoming by Murie (1930). He reported that of 193 elk autopsied, deaths were principally due to necrobacillosis, that the heaviest losses were among the calves, and next

[1] Paper No. 2277 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul, and Pittman-Robertson Project 11-R Division of Game Fish, Department of Conservation, cooperating.

among the older cows. His report mentions three deer dying of necrobacillosis. The symptoms noted in some animals were: initial lameness, with occasionally a great wad of food in one cheek (animals so affected were found to have full stomachs, and only in 4 or 5 cases was the food imperfectly chewed); other animals would first be found when down and unable to rise. Calves usually died the day following initial symptoms; adults often lingered much longer. In the latter there was a dejected attitude with the ears drooping and head held low; drooling was common, and breathing appeared painful. In a few cases the tongue was swollen and protruded; several animals finally "appeared to have fits," staggering about, jumping in an erratic manner until they fell, and exhibiting a sweeping motion of the legs in the death struggle.

The tissue changes due to necrobacillosis were described by Murie as follows: "The lesions, representing the original site of infection, vary greatly in size, and may extend deeply into the tissues. Pit-like erosions on surface of the tongue, cheek, or other mouth surface, filled with a pale yellowish, cheesy material. Favorite locations are the interalveolar spaces, and angle of the jaws back of the molars. There were peridental ulcers of the mucosa, exostosis of the mandible, bone necrosis. Ulcers in the stomach lining were common, and occasionally lesions due to this germ in the liver and spleen."

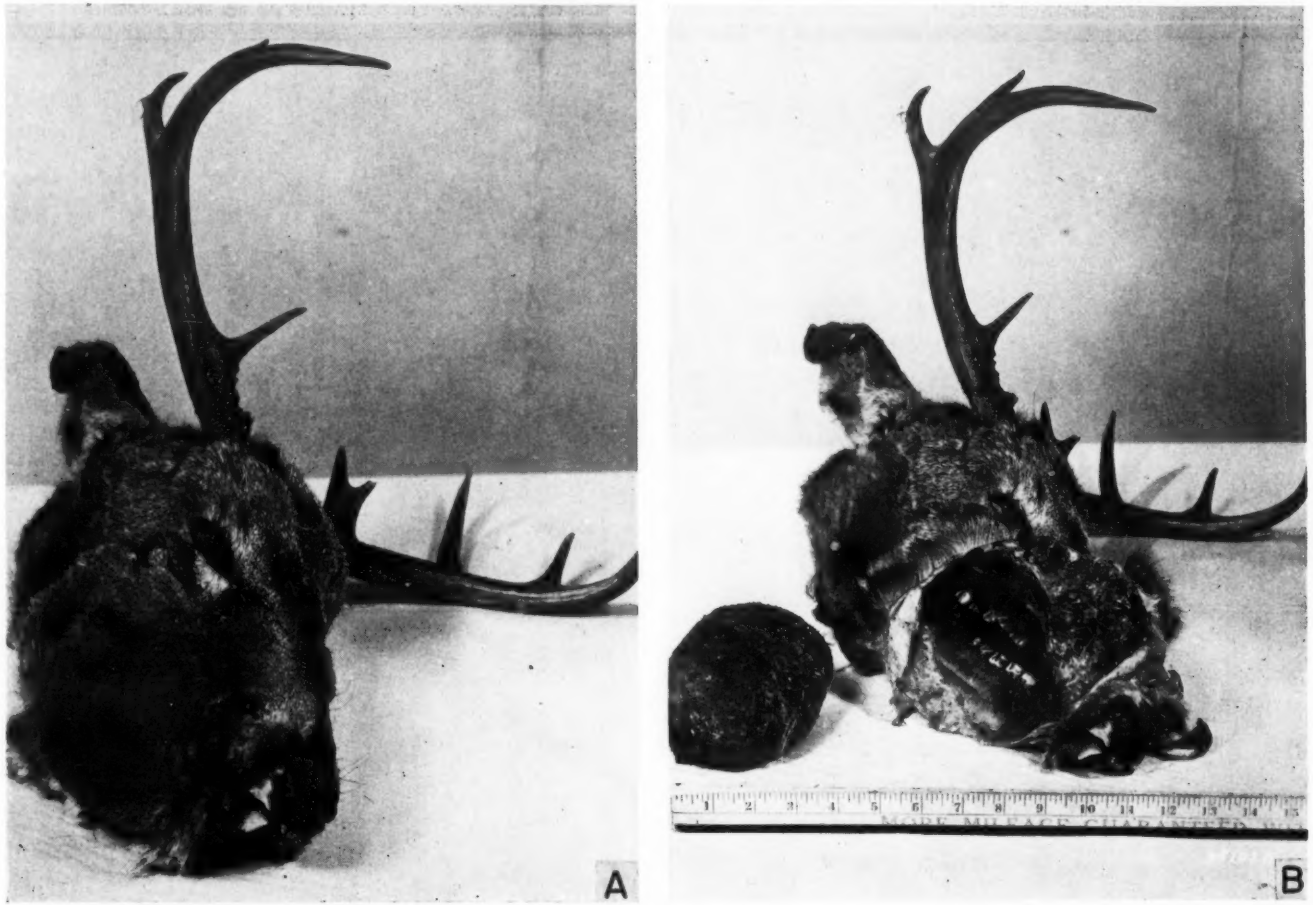
Murie found that the introduction of the germ was brought about principally by the awns of the meadow barley or Squirrel-tail grass (*Hordeum nodosum*). Short dried stem fragments of a rush (*Juncus*), were found in a few cases.

Rush (1932) in the Northern Yellowstone Park area examined 30 elk carcasses, and found lesions of necrobacillosis evident in twelve. Of 37 deer examined in the same area, 11 had the lesions of this disease. An ordinary pus organism (*Staphylococcus*) was found in several lesions in place of *Actinomyces;* of 13 antelope examined, six showed necrotic ulcers in the mouth.

Honess, and Frost (1942) during studies on Wyoming bighorn sheep autopsied one animal that showed "Ulceration of the second molar had occurred, and considerable enlargement of the jawbone had taken place. Small protuberances on the roots of the molar definitely indicated that the infection was bacterial."

McLean (1940) reported in a study of California deer that "disease takes considerable toll of deer in some areas. The most serious one is caused by the bacillus, *Actinomyces necrophorus*, which attacks the throat, mouth, feet, and in the advanced stages the lining of the stomach."

Murie, *et al.* (1944) reported further on the elk herd of the Jackson Hole Federal Elk Refuge, stating that "in 1942–43, 1,046 elk died on the feedground. Mortality resulted mainly from necrotic or ulcerative stomatitis . . . which in recent years has caused the death of almost 1/10 all elk wintering on the feedground." He considered necrobacillosis as a feedground disease, and noted a correlation between the death rate and the length of time animals were fed artificially in large concentrations. An attempt was made to lessen the incidence of this infection by feeding 600 calves during the winter 1933–34 on corn and second cutting



Buccal food impaction in whitetailed deer. *A*. External view showing enlargement of right cheek. *B*. Cheek opened and incised mass removed.

choice alfalfa; however the death loss in this group from necrotic stomatitis was a little more than 10 per cent, or slightly above the average feedground loss. In this special group the cause of the abrasions was not determined.

DISCUSSION

The organism causing necrobacillosis in deer, elk, antelope, and possibly bighorn sheep is not limited to wild species, but causes disease, or is associated with diseases, in cattle, sheep, hogs, horses, asses, goats, dog, fowl, rabbits, reindeer, and human beings. It also has been reported in the kangaroo, monkey, antelope, snake, and tortoise in zoological gardens.

The *Actinomyces necrophorus* is thought to occur over wide areas outside of animal bodies. It reaches the outside in the feces and saliva of infected animals, and in the feces of some apparently healthy individuals. This germ has no known mechanism to enable it to survive alone outside the body for more than a few hours, although in combination with pus bacteria (*Staphylococcus aureus*), and intestinal bacteria (*Escherichia coli*), it becomes "relatively insusceptible to destruction by air" (Beveridge, 1934), thus enabling it to survive under natural conditions.

The infection is taken into the body with contaminated food and water. It may attack the healthy tissues of the body, particularly the mouth, throat, stomach, and intestinal lining, or may gain entrance through bruises and openings in the skin and mucosa in association with other bacteria, particularly the pus forming bacteria commonly found in bruises (Hutyra, Marek, and Manninger, 1938).

The damage produced by *A. necrophorus* results from two toxic chemical substances: the exotoxin produced by the bacteria in the environment in which they live; and an endotoxin which is a part of the body of the bacteria. The exotoxin produces inflammation and death of cells of the skin, but does not form pus when injected under the skin; however it results in death or loss of weight in 24 hours when injected into the blood of domestic rabbits. A sheep injected intravenously with exotoxin showed diarrhea, difficult breathing, loss of appetite for one to three days, and then recovery.

The endotoxin caused the cells under the skin to die, but the skin cells did not seem to be affected when guinea pigs, and rabbits were injected. Rabbits given endotoxin directly into the blood lost considerable weight (Beveridge, 1934).

Thus there may be potent toxins circulating in the bodies of infected animals, in addition to the local cell destruction in big game mammals affected by necrobacillosis. The local lesions do not account satisfactorily for the rapid deaths associated with this condition. The toxins associated with *Actinomyces necrophorus* may however, offer an explanation.

Eruption of the teeth in younger animals, and the loosening and loss of teeth in aged animals provide natural and effective entrances for infection, which may account in part for the more frequent occurrence of this disease in calves and aged animals.

Since *A. necrophorus* is found commonly in lesions in association with other germs, and since this bacterium is present in the feces of some ap-

Buccal food impaction in whitetailed deer. *A.* External view showing enlargement of right cheek. *B.* Cheek opened and incised mass removed.

parently healthy animals, decision is difficult as to whether its mere presence proves it to be disease-causing in a particular species of animal. The actual damage done in the particular species must be studied before diagnosing a death as due to necrobacillosis. In other words, lesions of necrobacillosis may be present and it may be possible to recover the bacterium from the lesions in a dead animal, yet the organism may be related to the cause of death only partly, or not at all. This is particularly true in those animal species where *A. necrophorus* forms only small localized lesions.

It has been suggested (Murie, 1930) that squirrel-tail (*Hordeum nodosum*) and similar noxious grasses be eliminated from hay, also that the haylands be improved, and managed so as to tend to keep animals scattered over wider areas. Transplantation was also suggested as a solution (Murie, 1944).

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BRIEFER ARTICLES

WATER WEEDS FOR SALE

Aquatic nurseries still sell water weeds to make "game fish reproduce faster and grow larger" although fish culturists have known for 5 or 6 years that these weeds are detrimental rather than beneficial. The continuance of this business practice is becoming a disgrace to the wildlife profession. Should the Wildlife Society take a stand against the misinformation still being distributed by game food nurseries? Should editors of outdoor magazines force their advertisers to drop misleading claims? I say that the answer is *yes* to these questions. It is time for every fish culturist to scrutinize his recommendations relative to putting water plants in ponds. The sportsman deserves to know the truth about water weeds.

It is true that "game fish depend upon a proper aquatic plant growth . . . " if you mean the microscopic plants. It is not true if you mean leafy plants. Leafy water plants are troublesome, they make pond management difficult and the fishing less successful. A number of commercial nurseries that sell duck foods recommend these plants for fish: spatterdock, *Potamogetons*, *Elodea*, waterlilies, water shield, pickerel plant, smartweed, ducksmeat, bulrushes, coontail, and other water plants that can be sold at a profit. None of these is beneficial to fish. Ten years ago the wildlife profession knew no better. The advertising claims were written then, no doubt, and followed early recommendations of our fish culturists. It is time to reverse them.

Today we must suggest that a nursery which continues to advocate water weeds for fish management is verging on the operation of a racket. In the past they unknowingly imposed on the unsuspecting public. There is no reason why they should continue to do so. My mail this week brought an advertisement with one plant—water hyacinth—crossed off. The nurseryman evidently found it impossible or improper to continue to sell this obnoxious plant. To us who live in the deep South, the water hyacinth is a symbol of the trouble caused by water weeds.

While I note the crossing out of water hyacinth, this nursery still encourages the fish enthusiast to buy waterlily and lotus as "food, shade, and cover for game fish." This firm could easily omit its misleading statements concerning these two, but most nurseries sell a dozen or more water plants advertised to improve fishing.

Nurseries selling duck foods have a legitimate field. Their efforts and good materials are needed to further wildlife conservation, but unfortunately, their stock-in-trade seems to include almost everything that is easily gathered from natural waters. Perhaps it is not their responsibility to see that their recommendations are honest and dependable. If not, the wildlife profession will do hunters and fishermen a real service by exposing the worthlessness of many plants which are now advertised as good or excellent duck foods.

We might quickly classify the water weeds sold commercially into four groups:

1. *Those that interfere with suitable duck foods* and therefore should never be bought, sold, or planted. Examples are: lotus, white water lily, *Elodea*, and spatterdock.

2. *Those that occur naturally everywhere* and need not be planted, such as ducksmeat, coontail, and cattails.

3. *Those that are of questionable use* such as marsh mallow, wampee, banana waterlily, button bush, watershield, pickerel plant, and no doubt others.

4. *Those that are really worth planting* because they are unquestioned sources of food for wild fowl. The following includes most of the duck foods of merit and gives a selection of dependable material for commercial business: Smartweeds, wild duck millet, chufas, potamogeton (the better species only), widgeon grass, wild celery, wild rice, bulrushes, arrow-head lilies, and spike rush (*Eleocharis* spp.). It is possible that some of these belong in group 2, but others could be added to this list.

Perhaps the majority of professional wildlife workers do not realize how many problems are caused by the misguided sale of water plants. Those of us who work with management of soil and water see almost daily the disappointment, waste, and trouble

which results. Not the least of the unfairness is the wasted effort that might have been turned to something good—work which could have actually produced better hunting and fishing, cleaner and healtheir pond waters.

Hundreds of pond owners have fallen for the glittering spectacle of "more and bigger fish" held forth by the aquatic nursery ads. Later they say, "We didn't know any better," and ask, "How can we get rid of the weeds?" The city park lake in Leesburg, Florida, was choked with *Elodea* in 1945. The pond was ugly, raised myriads of mosquitoes, and was utterly useless for fishing. Years ago an owner of four ponds in South Carolina filled his waters with the same plant. Fishing was never good. Many other southern ponds are in the same condition—choked with weeds that neither fish nor ducks can use.

It is time that the duck experts, fish culturists, and aquatic nurserymen got together to put more quality and less trouble in wildlife waters.—VERNE E. DAVISON, *Soil Conservation Service, Spartanburg, South Carolina.*

SURVIVAL OF BROOK TROUT IN WATER OF LOW OXYGEN CONTENT

Some interesting data on the ability of native brook trout (*Salvelinus fontinalis*) to survive in water of low oxygen content were secured at Northwood, New Hampshire, on Bean River, a small feeder of the Lamprey River, originating on the east slope of Saddleback Mountain. The station at which the following readings were taken is approximately 1½ miles from the source, and maximum flow during the year is about 20 gallons per second. During the summer, the flow decreases considerably and in 1946, owing to combined drought and logging on the watershed, the stream flow stopped entirely for about five weeks.

Date	Flow ft./sec.	Temp. °F.	Oxygen p.p.m.	CO^2 p.p.m.	pH
June 19	2.0	52	9.1	6	6.5
25	0.2	58	2.8	16	5.7
July 3	0.1	60	2.4	26	5.7
9	0	57	3.3	23	5.9
16	0	54	1.7	24	5.7
24	0	52	1.1	31	5.5
30	0	58	1.7	36	5.7
Aug. 6	1.5	59	6.8	15	5.9

On June 25, when the stream flow had dropped to 0.2 gallons per second and dissolved oxygen had gone down to 2.8 p.p.m., trout fingerlings were acting normally both in pools and in the small connecting riffles.

On July 3, fingerlings were not seen in the riffle areas, which then were mere trickles, and the fingerlings in the pools allowed an observer to approach closely before they darted under protecting rocks, logs, or overhanging banks. The pools were still full, averaging approximately 6 by 10 feet in surface measurement, and 6 to 18 inches in depth. Fingerlings were most numerous in pools with overhanging banks or good log cover.

On July 9 the stream was no longer flowing. The best pools had lowered approximately three inches, and shallower pools had disappeared completely. Investigation above the station disclosed a completely dry stream bed. The only surviving trout were in a series of four pools in a stretch of stream bed about 100 feet long. Fifteen fingerlings were observed in the pools, and there were undoubtedly others under protective banks and logs. The fish were very active, due to a slight increase in oxygen probably caused by a brief but heavy shower just prior to the readings.

On July 16 the trout were in evident distress. They would lie motionless unless a rapid movement was made by the observer, and their gill movements were rapid and pronounced.

On July 24, two of the smaller pools had shrunk to mere puddles only 2 or 3 feet across and about 4 inches deep. They were devoid of trout, and there is no question but that the fish had been taken by some predator. The other two pools also had shrunk, but still contained fingerlings. One pool measured 3 by 7 feet, with a maximum depth of 6 inches; a log at its upper end provided some shelter for the nine fingerlings observed. The

other pool was about 3 feet in diameter and about a foot deep; this was overhung by a small bank, and had other excellent cover provided by small logs and tree roots. Four trout were observed, and others undoubtedly were present under the cover. The fish in both pools were very listless, and would allow the observer to touch them before they darted off. Their gill movements were very rapid and the fish were obviously distressed.

On July 30, the pool that had nine trout the previous week was about 4 inches in maximum depth, and the trout were gone. Their sluggishness had undoubtedly made them easy prey. The smaller, deeper pool with better protective cover still contained several fingerlings; they lay motionless under cover and were not molested.

The observations of August 6 followed a period of heavy rains and stream flow, with accompanying full pools, had started. Four very active and alert fingerlings were seen in the stretch of stream that contained the pools under observation. Since the stream above had been completely dry, and upstream movement of trout from a beaver pond below the position studied was restricted except during periods of almost maximum flow by a series of small cascades and logs, the surviving trout must have come from the small pool where fish had been observed on July 30.

Gutsell (Ecology, 10: 77–96, 1929), in referring to some of his experiments, states, that "certain brook trout even survived for a day or so in water containing but 1.2 p.p.m. of oxygen at a temperature of 15.5 degrees Centigrade. Whether these listless individuals could have recovered after such severe treatment was not determined. . . . At a lower temperature a lower oxygen content supposedly would prove sufficient." The observations on Bean River support Gutsell's supposition, since the trout survived in water of 11.2° C. containing only 1.1 p.p.m. of oxygen. Recovery by trout that had experienced severe conditions is proved possible by the observation of very active and normal fish following resumption of normal stream conditions.— WILLIAM J. JAHODA, *Biological Institute, University of New Hampshire, Durham, New Hampshire.*

FOOD HABITS OF MICHIGAN OPOSSUMS[1]

Within recent years the opossum (*Didelphis v. virginiana*) has invaded portions of some northern states where formerly it was rare or absent. In Connecticut, Vermont, New York, Pennsylvania, Wisconsin, Minnesota, and Michigan the opossum has both extended its range and increased in numbers.

Old records indicate that opossums have existed in Michigan for a long period, but apparently were not plentiful in earlier years. The earliest record is for 1845 (Wood, 1922). There are other reliable reports of occurrence in early years, but the species probably was never so abundant as from 1928 to the present time. Its range in Michigan is roughly the southern third of the Southern Peninsula, and the animal is most abundant in the southern counties of that section. Figures compiled by the Department of Conservation from the compulsory kill reports of hunters and trappers showed that 10,723 opossums were taken in Michigan from November 1 to December 15, 1941.

Michigan sportsmen are primarily interested in the opossum's relations with other animals. Many believe that it is detrimental to more highly valued species, especially the ring-necked pheasant and cottontail rabbit.

In an attempt to evaluate its predatory status, the writer studied the food habits of the opossum during 1941 and 1942. Published material on the subject is scant; Lay (1942) gives pertinent data from a study of Texas opossums, and Dearborn (1932) on the food of Michigan opossums. Some findings are presented by Allen (1938), Haugen

[1] Aid in this study was received from B. T. Ostenson and H. R. Hunt, Zoology Department, Michigan State College, and from the Game Division, Michigan Department of Conservation.

(1942), and Stuewer (1943) incidental to other biological investigations in Michigan.

MATERIALS AND METHODS

This study included a series of 49 specimens gathered by fur dealers in November and December, 1941, and six trapped by the writer in September of that year. Of the 55, all but three contained food. Data on food in 78 stomachs collected during the autumn of 1933 and eight in the spring of 1934 were obtained from the files of the Game Division, Michigan Department of Conservation.[2]

Cans containing 1:10 formalin solution were left with fur dealers before the opossum season opened. After the animals were pelted, the carcases were slit open and preserved by the dealers, and later were collected and tagged.

Stomach analyses were made by washing the contents free of dirt while held in a sieve under a faucet; in a dissecting pan the various items were separated from one another and each kind put into a watch glass. When separation had been completed, excess water was removed by squeezing the material between layers of paper towels. The volume of each item in cubic centimeters was obtained by the displacement of water. Intestinal contents were handled in much the same way. The only deviation in method consisted of estimating the volumes of the various kinds of foods rather than taking separate volumetric readings. After separation the material was examined in the dissecting pan and the percentage that each item comprised of the total volume in the two intestines was estimated. Excess water was removed from the mass of material and the volume obtained by water displacement. The estimated percentages were employed in converting the volume of each item into cubic centimeters. These volumes for both stomach and intestinal material were finally converted into percentages.

Most of the opossums collected in 1941 had been killed by night hunters, and bait is seldom used by fur trappers in southern Michigan. Hence bait is considered of little significance in this study.

[2] The analyses of these latter had been made by C. S. Williams, U. S. Fish and Wildlife Service.

ANIMAL FOODS

COTTONTAIL RABBIT (*Sylvilagus floridanus mearnsii*). This comprised the greatest volume (31%) of any item found in the stomachs, but its frequency of occurrence (19%) was moderate. Flesh and fur were the main constituents, few bones or fragments being present.

Cottontails are the commonest game animal of southern Michigan, being most plentiful in the southern counties, where opossums are most prevalent. Some material apparently was carrion. The legal hunting seasons for the two animals overlapped when most of the opossum material was collected. Data on the autumn, 1933, specimens showed rabbit remains as 12 per cent by volume and 40 per cent by occurrence. Only a trace of rabbit was found in one of eight spring-caught opossums.

A study by Haugen (1942) of predation on rabbits in Michigan gave little evidence that opossums prey on them.

FOX SQUIRREL (*Sciurus niger rufiventer*). The fox squirrel is common in most of southern Michigan, being next to the rabbit in abundance, but squirrel flesh was found in only one stomach.

MICE. In all, six per cent of the stomach contents was of mice, *Microtus* being the only genus identified, although other genera were represented. The remains consisted of flesh, fur, and bones, the last broken into small pieces. Observation of captive opossums in the act of eating mice showed that such food is chewed rather thoroughly.

MOLE (*Scalopus aquaticus machrinus*). Mole flesh, including hair, had been eaten by three opossums, and comprised one per cent of the total stomach contents.

SHREWS. Two opossums had eaten shrews. The remains were mostly of hair, although one dentary bone with the teeth intact was found. Hair keys proved invaluable in identifying the remains of these and other mammals (Dearborn, 1939, Mathiak, 1938, Williams, 1938). One of the shrews was identified as *Blarina brevicauda*.

SKUNK (*Mephitis mephitis nigra*). A trace was found in one opossum.

OPOSSUM. Opossum composed nine per cent of the total stomach contents and appeared in four animals. This inclusion was mostly of flesh and hair. As with other larger animals eaten, there were few bone fragments. Small quantities of opossum hair were not regarded as part of the food.

PHEASANT (*Phasianus colchicus torquatus*). Only one of 52 stomachs contained pheasant remains; these comprised two per cent of the total food volume. Most of the opossums were collected in regions where pheasants are not especially plentiful, but this game bird was common enough so that it should have appeared more often in the digestive tracts if it has a significant place in the autumn diet of the opossum. The open hunting season increased the chances of pheasant flesh as carrion.

TABLE 1.—AUTUMN FOOD OF OPOSSUM IN SOUTHERN MICHIGAN (BASED ON 55 SPECIMENS TAKEN SEPT., NOV., DEC., 1941).

Animal food	52 stomachs		54 intestines	
	Volume per cent	Percentage occurrence	Volume, per cent	Percentage occurrence
Rabbit	31	19	15	22
Squirrel	1	2	tr.	2
Meadow vole	3	11	4	7
Miscellaneous mice	3	6	3	7
Skunk	tr.	2	tr.	2
Mole	1	6	2	4
Shrew	1	2	2	4
Opossum	9	8	4	6
Chicken	2	8	3	9
Miscellaneous birds	5	25	3	22
Bird eggs	tr.	4		
Snake	tr.	2	tr.	2
Salamander	1	2	tr.	2
Frog and Toad	1	4	tr.	2
Grasshoppers	6	77	5	63
Beetles	tr.	19	tr.	11
Miscellaneous insects	1	21	tr.	4
Crayfish	tr.	4	tr.	4
Snails and slugs	2	15	2	7
Earthworms	8	27	1	15
Unident. animal matter	6	10	8	17
Plant food				
Grapes	9	29	10	41
Apple	2	21	21	28
Pear	tr.	2	4	9
Peach	tr.	4	tr.	4
Pokeweed berries	tr.	10	5	28
Elderberries	tr.	2	tr.	6
Ground cherry	tr.	6	2	9
Nightshade fruit			tr.	4
Wheat and oats	tr.	4	tr.	2
Grass	5	69	2	46
Unident. plant matter	2	11	2	9

Dearborn (1932) noted that two-thirds of the 23.2 per cent of mammal remains found in the opossums he studied consisted of opossum flesh. These marsupials occasionally kill their own kind (Pray, 1921, Seton, 1929), but it seems likely that they feed more often on flesh of individuals killed on roads or by hunters who do not retrieve them.

No reference was found to pheasant remains in the 86 opossums collected in 1933 and 1934. Pheasants are abundant in south-

ern Michigan as shown by the kill of more than 1,250,000 cocks during the 21-day season of 1941.

CHICKEN. Domestic fowl represented another small portion (2%) of the total bulk in the stomachs examined; records from elsewhere indicate that poultry is taken fairly often by opossums. Of the opossums collected in the autumn of 1933, chicken comprised the largest item by volume (13%) and appeared in 22 digestive tracts. The eight spring-caught specimens showed volume and occurrence of 31 and 37 per cent. Dearborn noted that domestic fowl is a significant portion of opossum food, but states that this is mostly of refuse discarded when chickens and other birds are prepared for human consumption. Some of the chicken material seen by the writer was carrion.

MISCELLANEOUS BIRDS. Remains of various wild birds, excluding pheasant, comprised 3 per cent of the stomach contents.

SNAKES. Two small snakes were found in one stomach. These were not definitely identified, but they were probably green snakes (*Opheodrys v. vernalis*).

AMPHIBIANS. Only 1 per cent of total volume was of amphibian remains. Parts of either toads or frogs were found in two specimens, and two salamanders (*Ambystoma jeffersonianum*) had been eaten by one opossum. The small volume of amphibians probably reflected the fact that these animals are in hibernation by November.

GRASSHOPPERS. Grasshoppers composed a significant portion of the food. Despite their small size, they comprised 4 per cent of the total volume from 46 stomachs of November-caught and December-caught animals. In six September specimens, 32 per cent of stomach contents was of grasshoppers. This food may form a large part of the summer diet, and was frequent in these particularly late autumn opossums because exceptionally mild weather in the autumn of 1941 permitted grasshoppers to remain active longer than usual.

MISCELLANEOUS INSECTS. Fragments of beetles appeared in 10 stomachs, but the volume was small; apparently only one had been eaten in most instances. Remains of bugs (probably Pentatomids) were found in two stomachs, and ants in two others. Larvae were more numerous, lepidopteran remains being most often represented. Besides these, one sawfly larva, two cranefly larvae, and one May beetle larva were seen.

MOLLUSKS. Snails and slugs comprised 2 per cent of the stomach contents, snails in seven and slugs in one stomach.

EARTHWORMS. A considerable number of earthworms had been eaten by opossums, and made 8 per cent of the stomach contents The worm fragments were mostly from a large species. Large species of both *Helodrilus* and *Lumbricus* occur in Michigan.

The quantity of earthworms consumed is influenced considerably by availability. The autumn of 1941 was especially wet; during October at East Lansing the rainfall was 4.86 inches above normal. Such excessive moisture greatly increases the activity of earthworms above ground, and they therefore served as a more convenient source of food that autumn than in seasons of less precipitation. Earthworms comprised 5 per cent of the food bulk of the 1933 collection.

PLANT FOODS

GRAPES (*Vitis*). Grape berries comprised the greatest volume (9%) of any plant food, cultivated varieties being more frequent than wild species. The remains were chiefly of seeds and skins. Occasionally the "meat" of the berries was intact, but more often it had disintegrated and did not figure in the volumetric determinations. Grapes are grown extensively in southern Michigan.

APPLE. Apparently apples are eaten frequently by opossums, but the volume in stomachs was small (2%). Remains of apples, however, made the greatest volume (21%) estimated for any item in the intestines examined.

PEAR. Remains of pears were found in five animals, but composed a small percentage. As with apples, this item occurred more consistently and in greater volume in the intestines.

PEACH. Peaches were present in the stomachs of two animals collected during September.

POKEWEED (*Phytolacca americana*). Apparently this fruit is a favorite of opossums.

The volumetric significance of this item was greatly reduced by digestion. Only 0.5 per cent of the stomach contents comprised pokeberry remnants, but more than 5 per cent of intestinal materials were comprised of the only part remaining, and the volumetric significance was small.

GRASS. Grass comprised 5 per cent of the contents and appeared in nearly 70 per cent of the opossums examined. In many, however, the quantity was small. Some grass may have been taken incidentally, but the significant volume in other specimens suggested that it had been consciously sought, and sometimes served as an accessory food. Giles (1940) found a considerable amount of grass eaten by raccoons and concluded it probably was taken as roughage or tonic food.

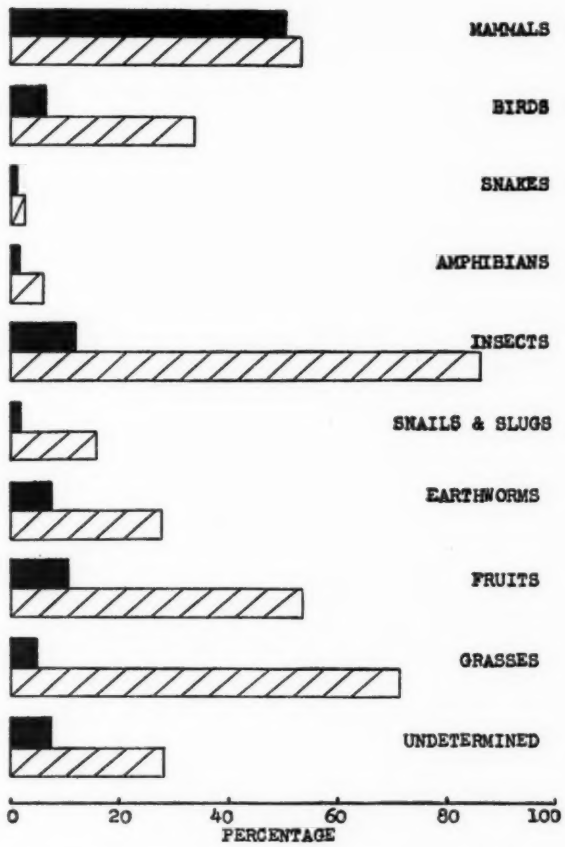

FIG. 1.—Foods in stomachs of 52 autumn-caught opossums in southern Michigan, 1941. Volume, black; occurrence shaded.

this plant. The remains were almost entirely of seeds.

ELDERBERRIES (*Sambucus*). Seeds were found in the stomachs and intestines of some specimens taken in September.

GROUND CHERRIES (*Physalis*). Fruits had been eaten by five animals. The thin pod which encloses the berry usually represented

DISCUSSION

Animal foods are more conspicuous than plant materials in the diet of Michigan opossums. In this study of 52 stomachs with food about four-fifths (81%) of the contents consisted of animal matter. Analysis of 54 intestines showed about equal partions of animal and plant remains (52–46%).

Differential digestion probably accounted for the rather pronounced disparity in composition of the contents in stomachs and intestines. Relatively more vegetative material resists digestion, hence stomach analyses probably afford a more accurate indication of food habits than do analyses of intestinal contents or fecal matter alone. The preferred method would appear to be examination of both stomachs and intestines, allowing observation of all the ingested material; occasionally an item is found in abundance in the intestinal tract which does not occur at all in the stomach.

Data on the food in 78 autumn specimens taken in 1933 showed 70 per cent of animal matter. This figure is almost identical with the findings of Dearborn (1932), of 69.6 per cent animal remains. These two lots of specimens gave results which differ from the results obtained by the writer by about 12 per cent.

The eight opossums taken in the spring of 1934 had about 90 per cent animal remains.

PREDATORY STATUS

This study showed that the flesh of rabbits and pheasants is not often eaten by Michigan opossums in the autumn. Both items occur often as carrion at that season, but they were present in the digestive tracts less frequently than was expected before the investigation began. A full estimate of the opossum's status in this regard cannot be drawn from the present findings, which concern autumn specimens almost entirely.

Studies on the food habits of the opossum in other seasons are needed, especially in the spring. This animal is known to eat eggs at times. It may prey on pheasant nests and young rabbits more extensively than it feeds upon the flesh of adults in fall. Yet rabbit and pheasant populations in Michigan were increasing along with that of the opossum, suggesting that any influence this marsupial exerts on the numbers of those species must be small on the whole.

SUMMARY

1. The opossum has extended its range and increased in numbers in many parts of the northern states within recent years. This change has stimulated discussion as to its effect on other wildlife in the new range.

2. In 1941 and 1942 the food of Michigan opossums was studied, 55 autumn-caught specimens being examined. In addition, the data on 78 other autumn-caught animals and eight spring-caught animals were examined and compared with findings made by the writer.

3. This study showed the opossum to be omnivorous, but exhibiting preference for animal foods. Stomach analysis revealed the proportion of approximately four-fifths animal food and one-fifth plant food.

4. Analyses of stomach and intestinal contents failed to support claims by hunters that opossums are highly detrimental to rabbits and pheasants.—CLARENCE M. TAUBE, *1022 Pearl Street, St. Joseph, Mich.*

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PROBABLE ERRORS IN SAMPLE MEASUREMENTS OF DEER KILL

The distribution of size classes of deer and other big game animals killed in any area may be used as an indicator of the management applied or needed. As the kill increases, the proportion of older deer in the take is reduced. Using as an example, an area where the legal take is limited to bucks, when females are thus protected the number of bucks reaching legal size should remain as constant as the female population. As hunting intensifies, a larger number of males are removed and a smaller number of juveniles have the opportunity to mature, the percentage of larger-size classes, therefore, declines.

If the production of larger animals is the objective, an analysis of size distribution furnishes a simple guide for applying proper management measures.

Weight and antler size are the qualities most sought by sportsmen. Of all simple measurements, that of antler beam diameter has the most significant correlation to these qualities.

In the six years prior to World War II (Johnson, Calif. Fish and Game, April, 1939) the U. S. Forest Service in California, in cooperation with the State Division of Fish and Game and others, took antler measurements of 70,000 deer and actual weights of about 15,000. Analysis of the weight data revealed a marked difference in weight frequencies as compared with the sizes indicated by the antler beam diameter measurements. In all cases there was a greater frequency in the larger-size classes of deer actually weighed.

It was then realized that, because the weighing was more or less voluntary on the part of the successful hunter, there was a greater desire to have the larger deer weighed This tendency was strongly evident in the data secured.

In order to determine the nature of the sample of weights, the kill on a portion of the Sierra National Forest was studied in 1940. About one-third of the kill on this forest funnels through a Ranger Station where hunters are registered. On their return the successful hunters were required to stop and antler measurements were made of all deer taken. About 30 per cent of the deer were actually weighed, hog-dressed, on convenient scales. The weights of all deer could not be secured

TABLE 1.—SIZE DISTRIBUTION OF DEER KILLED IN COMPARISON WITH A SAMPLE TAKEN FOR WEIGHT.

	Antler Beam Diameters						
	0.5, 0.6 & 0.7	0.8 & 0.9	1.0 & 1.1	1.2 & 1.3	1.4 & 1.5	1.6 & over	Total
Number of Deer Killed	117	216	140	68	60	16	617
Number Actually Weighed	22	59	45	32	19	6	183
Size of Sample Per cent	18.8	27.3	32.1	47.1	31.7	37.5	29.7

because some deer were partially eaten in camp (generally smaller ones); some had feet, head and other parts removed; and some hunters were in a hurry, etc. Many hunters were permitted to proceed when congestion would have resulted in considerable delay for some, if all deer were weighed.

Nevertheless, checkers were carefully instructed to secure a random sample, basing their decision to weigh a carcass on opportunity rather than willingness or desire by the hunter.

The frequency of distribution of antler beam diameter of all deer taken compared favorably with previous years when less than a 100 per cent sample was taken. There was still, however, a favoring of the larger sizes in the weight sample. This is shown in table 1.

The percentage of deer weighed with antler beam diameters less than 1 inch was less than the average size of the sample and the extremely small deer markedly smaller. The samples of what were considered adult deer (1 inch antler beam diameter and over) were all larger than average.

Our conclusions are:

1. By the checking station method used, random samples of weights cannot be secured.

2. A simple measurement that will correlate significantly with size will result in a much larger sample and will come much closer to actual distribution of size frequencies.—F. P. Cronmiller, *Division of Wildlife Management, United States Forest Service, San Francisco, California.*

NOTES

In the first issue of Volume 7 of the Journal of Wildlife Management, which appeared in January, 1943, Dr. Tracy I. Storer first published Suggestions to Authors for Preparing Manuscript and Illustrations. Since that time these clear, concise, and detailed suggestions have appeared on the inside of the back cover of each number of the Journal. It is probable that the continuous appearance of this material has led many to overlook its importance.

It would facilitate editorial work, produce cleaner copy and thus require less proof reading, and tend to eliminate errors in the final printed page, if *all* who submit manuscripts would carefully read these suggestions before preparing a final draft for presentation.

Attention might at this time be called to some of the more common errors. Tables are expensive to set and difficult to proof read. In their development, be sure that they are concise, illustrate the text, and do not contain more data than are really pertinent. Text figures should be, wherever possible, *black on white*, clear, and legible when reduced. Pasted labels should be firmly and smoothly attached to the figure. Otherwise they may come loose and be incorrectly replaced. Library paste is not good for this purpose; rubber cement is better. Illustrations from which half-tones will be made should be on glossy paper, preferably 5 × 7, and wherever possible all should be either horizontal views (i.e. the horizon parallel to the long dimension of the print) or all vertical (the horizon parallel to the short dimension). Then there are the old but inexcusable bug-a-boos of grammar and organization, errors for which there is little excuse. Statements should *all* be clear, concise and to the point in any scientific paper. Wordiness and heaviness of structure should be avoided. Lists of references cited should be according to the form used in this Journal.

If there is doubt as to the proper style or usage to employ, the best guide will be found to be the past issues of the Journal.—HARLOW B. MILLS, *Editor.*